

IEEE Std 3004.3™-2020

IEEE Recommended Practice for the
Application of Low-Voltage Fuses in
Industrial and Commercial Power
Systems



IEEE Recommended Practice for Application of Low-Voltage Fuses in Industrial and Commercial Power Systems

Developed by the

Industrial and Commercial Power Systems Standards Development Committee
of the
IEEE Industry Applications Society

Approved 24 September 2020

IEEE SA Standards Board

Abstract: The selection and application of low-voltage fuses used in North American industrial and commercial power systems is covered by this standard.

Keywords: branch circuit protective device, bus-bracing requirements, cable limiters, Class CC fuses, Class CD fuses, Class CF fuses, Class G fuses, Class J fuses, Class L fuses, Class R fuses, Class T fuses Class T fuses, commercial power systems, electrical design, fuse performance, high speed fuses, IEEE 3004.3™, industrial power systems, low-voltage fuses, motor overcurrent protection, non-current-limiting branch circuit fuses, overcurrent protective device, plug fuses, semiconductor fuses, short-circuit current ratings, supplemental fuses, supplementary protective device, test limiters, umbrella fuses

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

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PDF: ISBN 978-1-5044-7072-8 STD24416
Print: ISBN 978-1-5044-7073-5 STDPD24416

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Introduction

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IEEE 3000 Standards Collection®

This recommended practice was developed by the Industrial and Commercial Power Systems Standards Development Committee of the Industry Applications Society, as part of a project to repackaging the popular IEEE Color Books®. The goal of this project is to speed up the revision process, eliminate duplicate material, and facilitate use of modern publishing and distribution technologies.

When this project is completed, the technical material included in the 13 “color books” will be included in a series of new standards. Approximately 60 additional “dot” standards, organized into the following categories, will provide in-depth treatment of many of the topics formerly covered in the color books:

- Power Systems Design (3001 series)
- Power Systems Analysis (3002 series)
- Power Systems Grounding (3003 series)
- Protection and Coordination (3004 series)
- Emergency, Standby Power, and Energy Management Systems (3005 series)
- Power Systems Reliability (3006 series)
- Power Systems Maintenance, Operations, and Safety (3007 series)

In many cases, the material in a dot standard comes from a particular chapter of a particular IEEE Color Book. In other cases, material from several IEEE Color Books has been combined into a new dot standard.

IEEE Std 3004.3™

This publication provides a recommended practice for the electrical design of commercial and industrial facilities. It is likely to be of greatest value to the power-oriented engineer with limited commercial or industrial plant experience. It can also be an aid to all engineers responsible for the electrical design of commercial and industrial facilities. However, it is not intended as a replacement for the many excellent engineering texts and handbooks commonly in use, nor is it detailed enough to be a design manual. It should be considered a guide and general reference on electrical design for commercial and industrial facilities.

Tables, charts, and other information that have been extracted from codes, standards, and other technical literature are included in this publication. Their inclusion is for illustrative purposes; where technical accuracy is important, the latest version of the referenced document should be consulted to assure use of complete, up-to-date, and accurate information.

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IEEE Recommended Practice for Application of Low-Voltage Fuses in Industrial and Commercial Power Systems

1. Overview

1.1 Scope

This recommended practice covers the selection and application of low-voltage fuses used in North American industrial and commercial power systems.

1.2 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{1, 2}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

¹ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.

² The use of *will* is deprecated and cannot be used when stating mandatory requirements, *will* is only used in statements of fact.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

CSA C22.1, Canadian Electrical Code (CEC), Part I: Safety Standard for Electrical Installations.³

CSA C22.2 No. 248.1, Low Voltage Fuses—Part 1: General Requirements.

CSA C22.2 No. 248.2, Low Voltage Fuses—Part 2: Class C Fuses.

CSA C22.2 No. 248.3, Low Voltage Fuses—Part 3: Class CA and CB Fuses.

CSA C22.2 No. 248.4, Low Voltage Fuses—Part 4: Class CC Fuses.

CSA C22.2 No. 248.5, Low Voltage Fuses—Part 5: Class G Fuses.

CSA C22.2 No. 248.6, Low Voltage Fuses—Part 6: Class H Non-Renewable Fuses.

CSA C22.2 No. 248.7, Low Voltage Fuses—Part 7: Class H Fuses, Renewable.

CSA C22.2 No. 248.8, Low Voltage Fuses—Part 8: Class J Fuses.

CSA C22.2 No. 248.9, Low Voltage Fuses—Part 9: Class K Fuses.

CSA C22.2 No. 248.10, Low Voltage Fuses—Part 10: Class L Fuses.

CSA C22.2 No. 248.11, Low Voltage Fuses—Part 11: Plug Fuses.

CSA C22.2 No. 248.12, Low Voltage Fuses—Part 12: Class R Fuses.

CSA C22.2 No. 248.13, Low-Voltage Fuses—Part 13: Semiconductor Fuses.

CSA C22.2 No. 248.14, Low Voltage Fuses—Part 14: Supplemental Fuses.

CSA C22.2 No. 248.15, Low Voltage Fuses—Part 15: Class T Fuses.

CSA C22.2 No. 248.16, Low Voltage Fuses—Part 16: Test Limiters.

ICEA P-32-382, Short-Circuit Characteristics of Insulated Cable.⁴

IEC 60269-6, Low-Voltage Fuses—Part 6: Supplementary Requirements for Fuse-Links for the Protection of Solar Photovoltaic Energy System.⁵

IEC 60947-4-1, Low-Voltage Switchgear and Controlgear, Part 4: Contactors and Motor-Starters, Section One—Electromechanical Contactors and Motor-Starters.

IEEE Std 1584™, IEEE Guide for Performing Arc Flash Hazard Calculations.^{6, 7}

³ CSA publications are available from the Canadian Standards Association (<https://www.csa.ca/>).

⁴ ICEA publications are available from the Insulated Cable Engineers Association (<https://www.icea.org/>).

⁵ IEC publications are available from the International Electrotechnical Commission (<https://www.iec.ch>) and the American National Standards Institute (<https://www.ansi.org/>).

NEMA FU 1, Standard for Low-Voltage Cartridge Fuses.⁸

NFPA 70, National Electrical Code® (NEC®).^{9, 10}

UL 98, Standard for Enclosed and Dead-Front Switches.¹¹

UL 198M, Standard for Mine-Duty Fuses.

UL 248-1, Standard for Low-Voltage Fuses—Part 1: General Requirements.

UL 248-2, Standard for Low-Voltage Fuses—Part 2: Class C Fuses.

UL 248-3, Standard for Low-Voltage Fuses—Part 3: Class CA and CB Fuses.

UL 248-4, Standard for Low-Voltage Fuses—Part 4: Class CC Fuses.

UL 248-5, Standard for Low-Voltage Fuses—Part 5: Class G Fuses.

UL 248-6, Standard for Low-Voltage Fuses—Part 6: Class H Non-Renewable Fuses.

UL 248-7, Standard for Low-Voltage Fuses—Part 7: Renewable Fuses.

UL 248-8, Standard for Low-Voltage Fuses—Part 8: Class J Fuses.

UL 249-9, Standard for Low-Voltage Fuses—Part 9: Class K Fuses.

UL 248-10, Standard for Low-Voltage Fuses—Part 10: Class L Fuses.

UL 248-11, Standard for Low-Voltage Fuses—Part 11: Plug Fuses.

UL 248-12, Standard for Low-Voltage Fuses—Part 12: Class R Fuses.

UL 248-13, Standard for Low-Voltage Fuses—Part 13: Semiconductor Fuses.

UL 248-14, Standard for Low-Voltage Fuses—Part 14: Supplemental Fuses.

UL 248-15, Standard for Low-Voltage Fuses—Part 15: Class T Fuses.

UL 248-16, Standard for Safety, Low-Voltage Fuses—Part 16: Test Limiters.

UL 248-17, Standard for Safety, Low-Voltage Fuses—Part 17: Class CF Fuses.

UL 248-18, Standard for Safety, Low-Voltage Fuses—Part 18: Class CDFuses.

UL 248-19, Standard for Safety, Low-Voltage Fuses—Part 19: Photovoltaic Fuses.

UL 508, Standard for Industrial Control Equipment.

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⁷ IEEE publications are available from The Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>).

⁸ NEMA publications are available from the National Electrical Manufacturers Association (<https://www.nema.org/>).

⁹ NFPA publications are published by the National Fire Protection Association (<https://www.nfpa.org/>).

¹⁰ The NEC is published by the National Fire Protection Association (<https://www.nfpa.org/>). Copies are also available from the Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>).

¹¹ UL publications are available from Underwriters Laboratories (<https://www.ul.com/>).

UL 508E, UL LLC Outline of Investigation for IEC Type “2” Coordination Short Circuit Tests of Electromechanical Motor Controllers in Accordance with IEC Publications 947-4-1.

UL 977, Standard for Fused Power-Circuit Devices.

UL 1008, Standard for Transfer Switch Equipment.

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.¹²

ampere (current) rating: The root-mean-square (rms) or dc current that the fuse carries continuously without deterioration and without exceeding temperature rise limits specified for that fuse.

arcing time: The time elapsing from the melting of the current-responsive element (e.g., the link) to the final interruption of the circuit. This time depends on such factors as voltage and reactance of the circuit (see Figure 1).

body size: The set of dimensions of fuses within a fuse class or system. Each individual size covers a range of rated currents for which the specified dimensions remain unchanged.

coordination (selective): A general term describing the interrelated performance of overcurrent protective devices. Selective coordination is obtained when a minimum amount of equipment is removed from service for isolation of a fault or other abnormality.

current limiter: A device intended to function only on fault currents and not on lesser overcurrents regardless of time. Such a device is often used in series with a circuit breaker, which protects against overloads and low-level short circuits. However, cable limiters are types of current limiters that are used to provide short-circuit protection for cables, without being in series with another type of device.

current-limiting fuse: A fuse that interrupts all available currents above its threshold current and below its maximum interrupting rating, limits the clearing time at rated voltage to an interval equal to or less than the first major or symmetrical loop duration, and limits peak let-through current to a value less than the peak current that would be possible with the fuse replaced by a solid conductor of the same impedance (see Figure 1). Only Class CC, Class CD, Class CF, Class G, Class J, Class L, Class R, and Class T may be marked “current limiting.”

¹² *IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>.

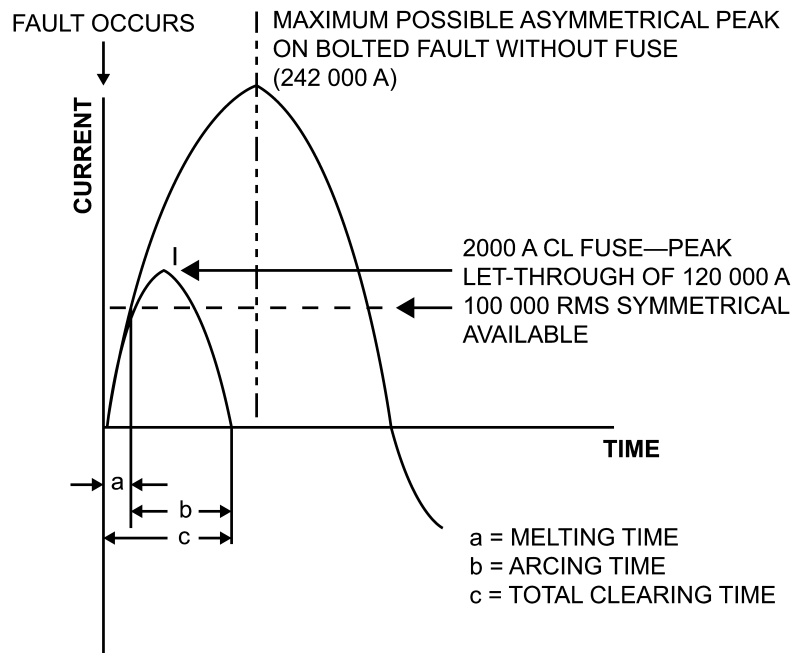


Figure 1—Current-limiting fuse showing peak let-through current and total clearing time

delay: A term usually applied to the opening time of a fuse when in excess of 1 cycle, where the time may vary considerably between types and manufacturers and still be within established standards. This word, in itself, has no specific meaning other than in manufacturers' claims unless published standards specify delay characteristics. *See: time delay.*

dual-element fuse: A cartridge fuse having two or more current-responsive elements of different fusing characteristics in series in a single cartridge. The dual-element design is a construction technique frequently used to obtain a desired time-delay response characteristic. *See: time delay.*

ferrule: The cylindrical-shaped fuse terminal that also encloses the end of the fuse. In low-voltage fuses, the design is only used in fuses rated up to and including 60 A. The ferrule may be made of brass or copper and may be plated with various materials.

full load: The greatest load that a circuit is designed to carry under specific conditions: any additional load is overload.

fuse-link: [British Standards Association (BSA) terminology] A complete enclosed cartridge fuse. The addition of a carrier, or holder, completes the fuse. [In the United States] A replaceable part or assembly that comprises entirely or principally the conducting element and is required to be replaced after each circuit interruption to restore the fuse to operating conditions. *See: link.*

high rupturing capacity (HRC): [British Standards Association (BSA) and Canadian Standards Association (CSA) terminology] A term equivalent to National Electrical Manufacturers Association (NEMA) high interrupting rating and generally indicating capability of interruption of at least 100 000 A root-mean-square (rms) for low-voltage fuses.

I^2t (ampere-squared seconds): The measure of heat energy developed within a circuit during the fuses melting or clearing. Generally stated as melting I^2t or clearing I^2t (see Figure 2).

COMPARE THE VOLUMES

EFFECTIVES CURRENTS

I'_1 = PEAK LET-THROUGH CURRENT
 I'_2 = EFF LET-THROUGH CURRENT (RMS)
 I_1 = AVAILABLE PEAK CURRENT
 I_2 = RMS CURRENT

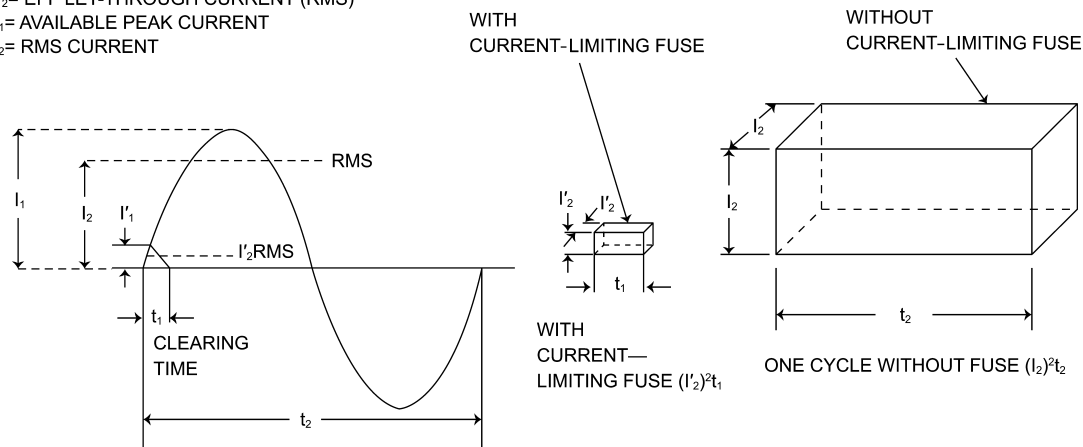


Figure 2—Graphic comparison of I^2t for current-limiting and non-current-limiting fuses

interrupting rating: The rating based on the highest root-mean-square (rms) ac or dc current that the fuse is tested to interrupt under the conditions specified. The interrupting rating, in itself, has no direct bearing on any current-limiting effect of the fuse.

link: The current-responsive element in a fuse that is designed to melt under overcurrent conditions and interrupt the circuit. A renewal link is one intended for use in Class H low-voltage renewable fuses.

melting time: The time required to melt the current-responsive element on a specified overcurrent. Where the fuse is current limiting, the melting time may be approximately half or less of the total clearing time. (Sometimes referred to as *pre-arcing time*.) (See Figure 1.)

nonrenewable (one time) fuse: A fuse or fuse unit not intended to be restored for service after circuit interruption.

overcurrent: Any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault.

overcurrent protective device, branch circuit: A device capable of providing protection for service, feeder, and branch circuits and equipment over the full range of overcurrents between its rated current and its interrupting rating. Branch circuit overcurrent protective devices are provided with interrupting ratings appropriate for the intended use but no less than 5000 A.

overcurrent protective device, supplementary: A device intended to provide limited overcurrent protection for specific applications and utilization equipment such as luminaires and appliances. This limited protection is in addition to the protection provided in the required branch circuit by the branch-circuit overcurrent protective device.

overload: Operation of equipment in excess of normal, full-load rating, or of a conductor in excess of rated ampacity which, when it persists for a sufficient length of time, would cause damage or dangerous overheating. A fault, such as a short circuit or ground fault, is not an overload.

peak let-through current (I_p): The maximum instantaneous current through a current-limiting fuse during the total clearing time. Because this value is instantaneous, it exceeds the root-mean-square (rms) available current, but is less than the peak current available without a fuse in the circuit if the fault level is high enough for it to operate in its current-limiting mode (see Figure 1).

plug fuses: Fuses that are rated 125 V and available with current ratings up to 30 A. Their use is limited to circuits rated 125 V or less. However, plug fuses may also be used in circuits supplied from a system having a grounded neutral and in which no conductor operates at more than 150 V to ground. The National Electrical Code® (NEC®) (NFPA 70) requires Type S fuses in all new installations of plug fuses because Type S fuses are tamper resistant and size limiting and thus make overfusing difficult.

pre-arcing time: *See: melting time.*

renewable fuse: A fuse in which the element, usually a zinc link, may be replaced after the fuse has opened. Once a popular item, this fuse is gradually losing popularity due to the possibility of using higher ampere-rated links or multiple links in the field. The National Electrical Code® (NEC®) (NFPA 70) prohibits the use of renewable fuses in new installations.

short-circuit current: An overcurrent, or more current than normal, that goes outside the normal current path when it is shunted around the load.

short-circuit current rating: The prospective symmetrical fault current at a nominal voltage to which an apparatus or system is able to be connected without sustaining damage exceeding defined acceptance criteria.

threshold current: The magnitude of current at which a fuse becomes current limiting, specifically, the symmetrical root-mean-square (rms) available current at the threshold of the current-limiting range, where the fuse total clearing time is less than 0.5 cycle at rated voltage and rated frequency, for a symmetrical closing, at a power factor of less than 20%.

threshold ratio: The ratio of the threshold current to the fuse's continuous-current rating.

time-current curve: A graphical plot (in log-log format) of curve that indicates the opening time of the fuse for various values of current. The curve can be either average melt, minimum melt, or total clearing.

time delay: A term used by National Electrical Manufacturers Association (NEMA), American National Standards Institute (ANSI), Underwriters Laboratories (UL), and Canadian Standards Association (CSA) to mean, in Class H, Class K, Class J, Class R, and Class CF (UL) fuses, a minimum opening time of 10 s on an overload current five times the ampere rating of the fuse, except for Class H, Class K, and Class R, 0 A to 30 A, 250 V body size where the minimum opening time can be reduced to 8 s for five times the rated current. Such time-delay is particularly useful in allowing the fuse to pass the momentary starting overcurrent of a motor, yet not hindering the opening of the fuse should the overload persist. In Class CC, Class CD, Class G, and plug fuses, the phrase *time-delay* requires a minimum opening time of 12 s on an overload of twice the fuse's ampere rating. The time-delay characteristic does not affect the fuse's short-circuit current clearing ability. Time-delay is in contrast with the term *nontime-delay* or *fast-acting* as applied to other fuse types.

total clearing time: The total time between the beginning of the specified overcurrent and the final interruption of the circuit, at rated voltage. It is the sum of the minimum melting time plus tolerance and the arcing time. For clearing times in excess of 0.5 cycle, the clearing time is substantially the maximum melting time for low-voltage fuses. (See Figure 1.)

uninterruptible power supply (UPS): A system designed to provide power automatically, without delay or transients, during any period when the normal power supply is incapable of performing acceptably.

voltage rating: The root-mean-square (rms) ac (or the dc) voltage at which the fuse is designed to operate. All low-voltage fuses function on any lower voltage, but use on higher voltages than rated is hazardous. For high short-circuit currents, increasing the voltage increases the arcing and clearing times and the clearing I^2t values.

4. General discussion

A low-voltage fuse is a current-responsive protective device with a circuit opening fusible part that is heated and severed by passage of current through it, creating an arc within the fuse. The interaction of the arc with certain other parts of the fuse results in current interruption.

NOTE—A fuse comprises all the parts that form a unit capable of performing the prescribed functions. It may or may not be the complete device necessary to connect it into an electric circuit.¹³

A fuse has these functional characteristics:

- a) It combines both the sensing and interrupting elements in one self-contained device.
- b) It is direct acting in that it responds to a combination of magnitude and duration of circuit current flowing through it.
- c) It normally does not include any provision for manually making and breaking the connection to an energized circuit, but requires separate devices (e.g., a disconnect switch) to perform this function.
- d) It is a single-phase device. Only the fuse in the phase or phases subjected to overcurrent responds to de-energize the affected phase or phases of the circuit or equipment that is faulty.
- e) After having interrupted an overcurrent, it is renewed by replacement of an equivalent fuse (or for renewable fuses, its current-responsive link) before restoration of service.
- f) Periodic maintenance or testing of fuses is not required to determine proper operation, but maintenance or testing of the switch or fuseholder in which the fuse is installed may be required.

5. Fuse types and standards

5.1 Introduction

The various fuse types and electrical industry standards about fuses are highlighted in this clause. Each is available from its source and should be studied for detailed requirements.

5.2 Fuse types

Per Article 100 of the NEC (NFPA 70), overcurrent devices, such as fuses, are defined as either branch circuit overcurrent protective devices or supplementary overcurrent protective devices. Branch circuit overcurrent protective devices can be used for protection of a service, feeder, or branch circuit of an electrical system. Supplementary overcurrent protective devices are not permitted to be used as a substitute or in place of a branch circuit overcurrent protective device per NEC 240.10 (NFPA 70-2017), or the Canadian Electrical Code (CEC) 14-114 (CSA C22.1-2018). However, in some limited applications, such as motor branch circuits, specific supplementary overcurrent protective devices, such as semiconductor (high speed) fuses, may be permitted for branch circuit short circuit and ground fault protection per the NEC (NFPA 70).

The fuse types that are branch circuit overcurrent protective devices per the NEC (NFPA 70) and CEC (CSA C22.1) include: plug fuses, Class CC, Class CD, Class CF, Class G, Class H, Class J, Class K, Class L, Class R, Class T. All of these fuses are current limiting with the exception of plug fuses and Class H

¹³ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

fuses. There are three basic advantages of current-limiting branch circuit fuses; high interrupting rating, ease of achieving selective coordination, and increased protection of components.

Class C, Class CA, Class CB high rupturing capacity (HRC) current-limiting fuses are permitted to be used in Canada per the CEC (CSA C22.1). Class C fuses are only permitted to be used for overcurrent protection where overload protection is provided by other means, such as short-circuit protection of a motor circuit where overload protection is provided by an overload relay. Class CA and Class CB fuses are permitted to be used as branch circuit protective devices.

The fuse types that are supplementary overcurrent protective devices include cable limiters, semiconductor (high speed) fuses, and supplemental fuses. Cable limiters are current limiters (but not marked “current limiting”). Semiconductor (high speed) fuses may be marked “current limiting.” Supplemental fuses are not permitted to be marked “current limiting.”

Test limiters (umbrella fuses) are not intended for use in electrical distribution systems and as such are not considered either branch circuit overcurrent protective devices or supplementary overcurrent protective devices.

5.3 Underwriters Laboratories (UL) and Canadian Standards Association (CSA)

5.3.1 Introduction

UL 248-1 and CSA C22.2 No. 248.1 provide general requirements for low-voltage fuses (1000 V or less). The UL 248 series of standards (1-16 and 19) has been harmonized with UL and CSA. Figure 3 shows the classification of low-voltage fuses covered by the standards.

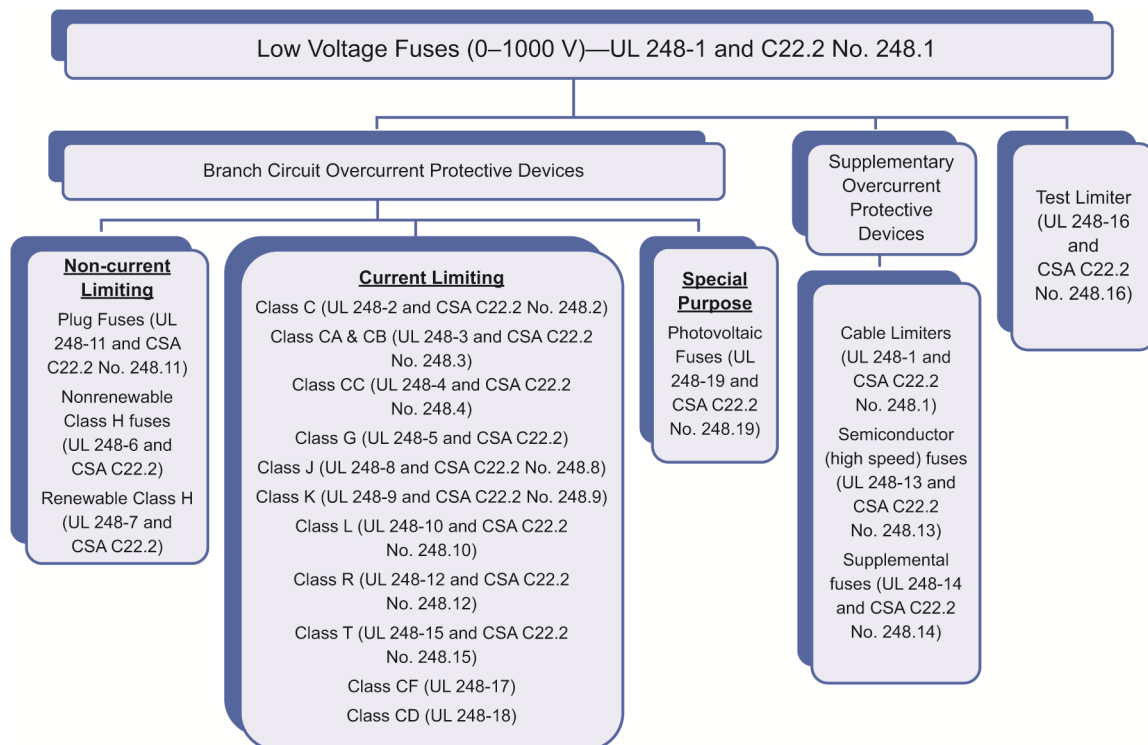


Figure 3—Low voltage fuses covered by UL and CSA

5.3.2 Non-current-limiting branch circuit fuses

5.3.2.1 Overview

Subclause 5.3.2 covers branch circuit fuse types that are non-current limiting.

5.3.2.2 Plug fuses

UL 248-11 and CSA C22.2 No. 248.11 cover Edison base, Type C, and Type S base plug fuses. Plug fuses have ac ratings to interrupt 10 000 A. Plug fuses have ampere ratings up to 30 A and an ac voltage rating of 125 V. Plug fuses may have an additional optional dc rating up to 125 V. These fuses are not recognized as being current limiting. As such, plug fuses cannot bear a marking that states or implies that plug fuses are current limiting. Plug fuses may be either fast-acting or time-delay. If marked “time delay” or similarly, plug fuses are required to have a minimum opening time of 12 s when subjected to a load of two times rated current. Type C and Type S fuses for Canada with low melting-point characteristics are marked with a “P” or “D” for time delay. Type C and Type S base plug fuses have rejection features for ampere ratings in the ranges of 0 A to 15 A, 16 A to 20 A, and 21 A to 30 A that limit the ampere rating of fuses that may be installed in a particular fuse socket. Edison base plug fuses are interchangeable for all current ratings and as such are not permitted for new installations per NEC 240.51 (NFPA 70-2017) and CEC 14-204 (CSA C22.1-2018).

5.3.2.3 Class H fuses

UL 248-6 and CSA C22.2 No. 248.6 cover nonrenewable Class H fuses. UL 248-7 and CSA C22.2 No. 248.7 cover standard renewable Class H fuses. Class H fuses have ac ratings to interrupt up to 10 000 A. Class H fuses have ampere ratings up to 600 A with voltage ratings of 250 V or 600 V. Class H fuses may have an additional optional dc rating up to 600 V. Class H fuses are available in six body sizes (0 A to 30 A, 31 A to 60 A, 61 A to 100 A, 101 A to 200 A, 201 A to 400 A, and 401 A to 600 A). These fuses are not recognized as being current limiting. As such, Class H fuses cannot bear a marking that states or implies that Class H fuses are current limiting. Fuses marked “time-delay” or “D” are required to have a minimum opening time of 10 s at five times their rating, except for the 250 V, 30 A body size, which has a minimum 8 s opening time at five times their rating. Class H fuses for Canada with low melting point characteristics are marked with a “P” or “D” for time delay. Renewable Class H fuses are not permitted in new installations per NEC 240.60(D) (NFPA 70-2017).

- a) Continuous-current-carrying ability and temperature rise.
- b) Overload operation within prescribed maximum times at 135% and 200% of the fuse’s continuous-current rating.
- c) Time-delay test (optional) for a minimum opening time of 10 s at five times the continuous-current rating, except for fuses of 0 A to 30 A, 250 V, minimum clearing time may be reduced to 8 s at 500%. A fuse may be labeled “time delay” only if it passes this test.
- d) Short-circuit interrupting capability at 10 000 A root-mean-square (rms) (ac). DC testing is optional.

5.3.3 Current-limiting branch circuit fuses

Nonrenewable current-limiting branch circuit fuses that limit the peak let-through current and the total I^2t and that exhibit current-limiting characteristics above specified values of threshold current. Each of the fuse classes, with the exception of Class K, has prescribed values for threshold current. All of the fuse classes have prescribed maximum peak let-through currents and I^2t at fault current levels at their marked

interrupting rating or at multiple values of fault current. Current-limiting branch circuit fuses, with the exception of Class K, also have different dimensional characteristics than Class H fuses or a rejection feature to meet the noninterchangeability requirements of current-limiting fuses per NEC Article 240.60(B) (NFPA 70-2017).

5.3.3.1 Class K

UL 248-9 and CSA C22.2 No. 248.90 cover nonrenewable Class K fuses made in the same dimensions as Class H fuses, but which have an ac rating to interrupt 50 000 A, 100 000 A, or 200 000 A rms. Class K fuses have ampere ratings up to 600 A with voltage ratings of 250 V or 600 V. Class K fuses may have additional optional dc ratings up to 600 V. Class K fuses are tested for continuous-current-carrying ability, temperature rise, overload opening, and an optional time-delay test of 10 s (8 s for 250 V, 30 A body size) at five times the current rating in order to be labeled as “time delay.” Because Class K fuses have no prescribed threshold ratio and are interchangeable with Class H fuses, Class K fuses are not marked “current limiting.” Class K fuses are also tested at various short-circuit levels up to their maximum interrupting rating and for compliance with prescribed maximum values of peak let-through current and I^2t at fault current levels of 50 000 A, 100 000 A, and 200 000 A for each body size (0 A to 30 A, 31 A to 60 A, 61 A to 100 A, 101 A to 200 A, 201 A to 400 A, and 401 A to 600 A) and each of the three divisions: K-1, K-5, and K-9. K-1 fuses are required to have the lowest I^2t and I_p let-through values. K-5 fuses are allowed to have higher values, and K-9 fuses have the highest I^2t and I_p limits. Class K fuses are marked for the class subdivision, interrupting rating, amperes, and maximum voltage. Class K fuses are obsolete and recommended to be replaced with Class R fuses.

5.3.3.2 Class R

UL 248-12 and CSA C22.2 No. 248.12 cover nonrenewable Class R fuses. Class R fuses have two subclasses, either subclass RK-1 or subclass RK-5. Class R fuses are labeled as “current limiting” and have ac ratings to interrupt 200 000 A or 300 000 A. Class R fuses have ampere ratings up to 600 A with voltage ratings of 250 V or 600 V. Class R fuses may have additional optional dc ratings up to 600 V. Class R fuses are tested for continuous-current-carrying ability, temperature rise, overload opening, and an optional time-delay test of 10 s (8 s for 250 V, 30 A body size) at five times the current rating in order to be labeled as “time delay.”

Class R fuses are also tested at various short-circuit levels up to their maximum interrupting rating and for compliance with prescribed maximum values of threshold current, peak let-through current, and I^2t at fault current levels of 50 000 A, 100 000 A, 200 000 A, and 300 000 A if applicable, for each body size (0 A to 30 A, 31 A to 60 A, 61 A to 100 A, 101 A to 200 A, 201 A to 400 A, and 401 A to 600 A). The maximum peak let-through currents for each body size are also expressed by equations in order to determine the peak let-through current at intermediate values of fault currents. Subclass RK-1 has the lower (or more restrictive) peak let-through current and I^2t values as compared to subclass RK-5 as shown in Table 1.

Table 1—Maximum peak let-through current and clearing I^2t for Class R fuses
(Reprinted with permission from UL)

Current Rating I _n , A	Between threshold and 25 kA		At 50 kA		At 100 kA		At 200 kA		At 300 kA		Peak let-through Function ^a
	Peak Let-through current, kA	I ² t Ampere-squared seconds X 10 ³	Peak Let-through current, kA	I ² t Ampere-squared seconds X 10 ³	Peak Let-through current, kA	I ² t Ampere-squared seconds X 10 ³	Peak Let-through current, kA	I ² t Ampere-squared seconds X 10 ³	Peak Let-through current, kA	I ² t Ampere-squared seconds X 10 ³	
Class RK1											
0 - 30	6	10	6	10	8.7	10	12	11	16	13	Y = 3.71E – 02X + 5E + 03
31 - 60	9	40	10	40	12	40	16	50	20	60	Y = 0.04X + 8000
61-100	13	100	14	100	16	100	20	100	24	120	Y = 0.04X + 12000
101-200	16	400	18	400	22	400	30	400	38	480	Y = 8E – 02X + 1.4E + 04
201-400	32	1,200	33	1,200	35	1,200	50	1,600	79	1,920	Y = 7.3E – 07X ² – 7E – 02X + 3.47E + 04
401 - 600	43	3,000	45	3,000	50	3000	70	4,000	104	4,800	Y = 6.7E – 07X ² + 4.33E + 04
Class RK5											
0 - 30	11	50	11	50	11	50	14	50	21	60	Y = 2.0E-07X ² - 3E-02X + 1.2E+04
31 - 60	20	200	20	200	21	200	26	200	35	240	Y = 2.0E-07X ² - 1E-02X + 2.0E+03
61-100	21	500	22	500	25	500	32	500	40	600	Y = 6.7E-08X ² - 5E-02X + 1.93E+04
101-200	30	1,600	32	1,600	40	1,600	50	2,000	62	2,400	Y = 1.17E-01X + 2.7E+04
201-400	-	-	50	5,200	60	5,000	75	6,000	90	7,200	Y = 1.64E-01X+ 4.25E+04
401 - 600	-	-	65	10,000	80	10,000	100	12,000	124	14,4000	Y = 2.286E-01X+ 5.5E+04

^a The value of X in the equation is the value of the prospective short circuit current in A (e.g. 50,000, 100,000, 200,000 or 300,000) or as intended by the author.

Class R fuses have a rejection feature (notch in fuse ferrule or blade) that is not found in Class H and Class K fuses to meet the noninterchangeability requirements of current-limiting fuses per NEC Article 240.60(B) (NFPA 70). Class R fuseholders are designed to accept the rejection feature of Class R fuses, but do not accept Class H or Class K fuses or any other class. However, Class R fuses do fit into Class H or Class K fuseholders. Class R fuses are labeled for the subclass, interrupting rating, ampere rating, and maximum voltage rating.

5.3.3.3 Class J

UL 248-8 and CSA C22.2 No. 248.8 cover Class J fuses. Class J fuses are labeled as “current-limiting” and have ac rating to interrupt 200 000 A or 300 000 A. Class J fuses have ampere ratings up to 600 A and an ac voltage rating of 600 V. Class J fuses may have an additional optional dc rating up to 600 V. Class J fuses may be either fast-acting or time-delay. If marked “time delay” or similarly, Class J fuses are required to have a minimum opening time of 10 s when subjected to a load of five times rated current.

Class J fuses are also tested at various short-circuit levels up to their maximum interrupting rating and for compliance with prescribed maximum values of threshold current, peak let-through current, and I^2t at fault current levels of 50 000 A, 100 000 A, 200 000 A, and 300 000 A if applicable, for each body size (0 A to 30 A, 31 A to 60 A, 61 A to 100 A, 101 A to 200 A, 201 A to 400 A, and 401 A to 600 A). The maximum peak let-through currents for each body size are also expressed by equations in order to determine the peak let-through current at intermediate values of fault currents. Class J fuses have additional maximum peak let-through current and I^2t values at a fault current of 100 000 A for intermediate ampere ratings as shown in Table 2.

Table 2—Maximum peak let-through current and clearing I^2t for Class J fuses
(Reprinted with permission from UL)

Current rating I_n , A	Between threshold and 50 kA		At 100 kA		At 200 kA		At 300 kA, if applicable		Peak Let-Through Function
	Peak let-through current, A	I^2t , ampere-squared seconds	Peak let-through current, A	I^2t , ampere-squared seconds	Peak let-through current, A	I^2t , ampere-squared seconds	Peak let-through current, A	I^2t , ampere-squared seconds	
1			1,000	800					
3			1,500	1,200					
6			2,300	2,000					
10			3,300	3,000					
15			4,000	4,000					
20			5,000	5,000					
25			6,000	5,500					
30	6,000	7,000	7,500	7,000	12,000	7,000	18,500	8,400	$Y = 1E-07x^2 + 0.015x + 5000$
35			7,500	12,000					
40			8,000	17,000					
45			8,500	18,000					
50			9,000	22,000					
60	8,000	30,000	10,000	30,000	16,000	30,000	24,367	36,000	$Y = 1E-07x^2 + 0.02x + 6666.7$
70			11,500	50,000					
80			12,500	60,000					
90			13,500	75,000					
100	12,000	60,000	14,000	80,000	20,000	80,000	28,367	96,000	$Y = 1E-07x^2 + 0.02x + 10667$
110			14,500	100,000					
125			15,500	150,000					
150			17,000	175,000					
175			18,500	225,000					
200	16,000	200,000	20,000	300,000	30,000	300,000	42,367	360,000	$Y = 1E-07x^2 + 0.06x + 12667$
225			22,500	350,000					
250			24,000	450,000					
300			26,000	600,000					
350			29,000	800,000					

Table 2—Maximum peak let-through current and clearing I^2t for Class J fuses
(Reprinted with permission from UL) (*continued*)

Current rating I_n , A	Between threshold and 50 kA		At 100 kA		At 200 kA		At 300 kA, if applicable		Peak Let-Through Function
	Peak let-through current, A	I^2t , ampere-squared seconds	Peak let-through current, A	I^2t , ampere-squared seconds	Peak let-through current, A	I^2t , ampere-squared seconds	Peak let-through current, A	I^2t , ampere-squared seconds	
400	25,000	1,000,000	30,000	1,100,000	45,000	1,100,000	66,367	1,320,000	$Y = 3E-07x^2 + 0.05x + 21667$
450			36,000	1,500,000					
500			42,000	2,000,000					
600	35,000	2,500,000	45,000	2,500,000	70,000	2,500,000	101,367	3,000,000	$Y = 3E-07x^2 + 0.15x + 26667$

Class J fuses offer space savings and increased current limitation when compared to Class H, Class K, and Class R fuses. However, Class J fuses typically do not have as much time-delay capabilities as Class R fuses.

5.3.3.4 Class T

UL 248-15-2000 and CSA C22.2 No. 248.15-2000 cover Class T fuses. Class T fuses are labeled as “current limiting” and have ac ratings to interrupt 200 000 A. Class T fuses have ampere ratings up to 1200 A and ac voltage rating of 300 V or 600 V. Class T fuses may have an additional optional dc rating up to 600 V. Class T fuses are very compact in size and very current-limiting. Class T fuses may be either fast-acting or time-delay. If marked “time delay” or similarly, Class T fuses are required to have a minimum opening time of 10 s when subjected to a load of five times rated current.

Class T fuses are also tested at various short-circuit levels (at 300 V and 600 V) up to their maximum interrupting rating and for compliance with prescribed maximum values of threshold current, peak let-through current, and I^2t at fault current levels of 50 000 A, 100 000 A, and 200 000 A for each body size (0 A to 30 A, 31 A to 60 A, 61 A to 100 A, 101 A to 200 A, 201 A to 400 A, 401 A to 600 A, 601 A to 800 A, and 801 A to 1200 A). Class T fuses have additional maximum peak let-through current and I^2t values at a fault current of 100 000 A for intermediate ampere ratings as shown in Table 3 and Table 4. The maximum values of peak let-through current and I^2t for 600 V Class T fuses are the same as that required for Class J fuses.

**Table 3—Maximum peak let-through current and clearing I^2t for 300 V Class T fuses
(Reprinted with permission from UL)**

Current rating I_n , A	Between threshold and 50 kA		At 100 kA		At 200 kA	
	Peak let-through current, A	I^2t , ampere-squared seconds	Peak let-through current, A	I^2t , ampere-squared seconds	Peak let-through current, A	I^2t , ampere-squared seconds
1			800	400		
3			1300	600		
6			2000	1000		
10			3000	1500		
15			4000	2000		
20			4500	2500		
25			5500	2700		
30	5,000	3,500	7000	3500	9,000	3500
35			7000	6000		
40			7200	8500		
45			7600	9000		
50			8000	11,000		
60	7,000	15,000	9000	15,000	12,000	15,000
70			10,000	25,000		
80			10,700	30,000		
90			11,600	38,000		
100	9,000	40,000	12,000	40,000	15,000	40,000
110			12,000	50,000		
125			13,000	75,000		
150			14,000	88,000		
175			15,000	115,000		
200	13,000	150,000	16,000	150,000	20,000	150,000
225			21,000	175,000		
250			22,000	225,000		
300			24,000	300,000		
350			27,000	400,000		
400	22,000	550,000	28,000	550,000	35,000	550,000
450			32,000	600,000		
500			37,000	800,000		
600	29,000	1,000,000	37,000	1,000,000	46,000	1,000,000
700			45,000	1,250,000		
800	37,000	1,500,000	50,000	1,500,000	65,000	1,500,000
1000			65,000	3,500,000		
1200	50,000	3,500,000	65,000	3,500,000	80,000	4,000,000

Table 4—Maximum peak let-through current and clearing I^2t for 600 V Class T fuses
(Reprinted with permission from UL) (*continued*)

Current rating I_n , A	Between threshold and 50 kA		At 100 kA		At 200 kA	
	Peak let-through current, A	I^2t , ampere-squared seconds	Peak let-through current, A	I^2t , ampere-squared seconds	Peak let-through current, A	I^2t , ampere-squared seconds
1			1000	800		
3			1500	1200		
6			2300	2000		
10			3300	3000		
15			4000	4000		
20			5000	5000		
25			6000	5500		
30	6,000	7,000	7500	7000	12,000	7000
35			7500	12,000		
40			8000	17,000		
45			8500	18,000		
50			9000	22,000		
60	8,000	30,000	10,000	30,000	16,000	30,000
70			11,500	50,000		
80			12,500	60,000		
90			13,500	75,000		
100	12,000	60,000	14,000	80,000	20,000	80,000
110			14,500	100,000		
125			15,500	150,000		
150			17,000	175,000		
175			18,500	225,000		
200	16,000	200,000	20,000	300,000	30,000	300,000
225			22,500	350,000		
250			24,000	450,000		
300			26,000	600,000		
350			29,000	800,000		
400	25,000	1,000,000	30,000	1,100,000	45,000	1,100,000
450			36,000	1,500,000		
500			42,000	2,000,000		
600	35,000	2,500,000	45,000	2,500,000	70,000	2,500,000
700			50,000	3,500,000		
800	50,000	4,000,000	55,000	4,000,000	75,000	4,000,000
1000			65,000	8,000,000		
1200	55,500	10,000,000	70,000	10,000,000	88,000	10,000,000

5.3.3.5 Class L

UL 248-10 and CSA C22.2 No. 248.10 cover Class L fuses. Class L fuses are labeled as “current limiting” and have ac rating to interrupt 200 000 A or 300 000 A. Class L fuses have ampere ratings in the range of 601 A to 6000 A and ac voltage rating of 600 V. Class L fuses may have an additional optional dc rating up to 600 V. Class L fuses have specified dimensions larger than those of other fuses rated 600 V (or less). Class L fuses are intended to be bolted to bus bars and are not used in clips. UL has no definition of time delay for Class L fuses; however, many Class L fuses have substantial overload time-current carrying capability.

Class L fuses are also tested at various short-circuit levels up to their maximum interrupting rating and for compliance with prescribed maximum values of threshold current, peak let-through current, and I^2t at fault current levels of 50 000 A, 100 000 A, 200 000 A, or 300 000 A, if applicable, for each body size (601 A

to 800 A, 801 A to 1200 A, 1201 A to 1600 A, 1601 A to 2000 A, 2001 A to 2500 A, 2501 A to 3000 A, 3001 A to 4000 A, 4001 A to 5000 A, and 5001 A to 6000 A). The maximum peak let-through currents for each body size are also expressed by equations in order to determine the peak let-through current at intermediate values of fault currents as shown in Table 5.

Table 5—Maximum peak let-through current and clearing I^2t for Class L fuses
(Reprinted with permission from UL)

Current Rating I_n , A	Between threshold and 50 kA		At 100 kA		At 200 kA		At 300 kA if applicable		Peak let-through Function
	Peak Let-through current, A	I^2t Ampere-squared seconds	Peak Let-through current, A	I^2t Ampere-squared seconds	Peak Let-through current, A	I^2t Ampere-squared seconds	Peak Let-through current, A	I^2t Ampere-squared seconds	
0 – 100	12,000	60,000	14,000	80,000	20,000	80,000	28,367	96,000	$Y = 1E-07X^2 + 0.02X + 10667$
101 – 200	16,000	200,000	20,000	300,000	30,000	300,000	42,367	360,000	$Y = 1E-07X^2 + 0.06X + 12667$
201 – 400	25,000	1,000,000	30,000	1,100,000	45,000	1,100,000	66,367	1,320,000	$Y = 3E-07X^2 + 0.05X + 21667$
401 – 600	35,000	2,500,000	45,000	2,500,000	70,000	2,500,000	101,367	3,000,000	$Y = 3E-07X^2 + 0.15X + 26667$
601 – 800	80,000	10,000,000	80,000	10,000,000	80,000	10,000,000	79,200	12,000,000	$Y = 3E-07X^2 + 0.3287X + 30712$
801 – 1200	80,000	12,000,000	80,000	12,000,000	120,000	15,000,000	107,800	18,000,000	$Y = -4E-07X^2 + 0.3206X + 48138$
1201 – 1600	100,000	22,000,000	100,000	22,000,000	150,000	30,000,000	143,000	36,000,000	$Y = -9E-07X^2 + 0.5678X + 52225$
1601 – 2000	110,000	35,000,000	120,000	35,000,000	165,000	40,000,000	158,400	48,000,000	$Y = -8.44E-07X^2 + 0.552X + 69400$
2001 – 2500	-	-	165,000	75,000,000	180,000	75,000,000	170,500	90,000,000	$Y = -8E-07X^2 + 0.5775X + 71500$
2501 – 3000	-	-	175,000	100,000,000	200,000	100,000,000	225,500	120,000,000	$Y = -8.44E-07X^2 + 0.552X + 69400$
3001 – 4000	-	-	220,000	150,000,000	250,000	150,000,000	286,000	180,000,000	$Y = -8E-07X^2 + 0.6875X + 63500$
4001 – 5000	-	-	-	350,000,000	300,000	350,000,000	286,000	420,000,000	$Y = -1E-06X^2 + 1.035X + 97000$
5001 – 6000	-	-	-	350,000,000	350,000	500,000,000	399,300	600,000,000	

5.3.3.6 Class CC

UL 248-4 and CSA C22.2 No. 248.4 cover Class CC fuses. Class CC fuses are labeled as “current-limiting,” and have an ac rating to interrupt 200 000 A rms. Class CC fuses have ampere ratings up to 30 A and an ac voltage rating of 600 V. Class CC fuses may have an additional optional dc rating up to 600 V. Class CC fuses may be either fast-acting or time-delay. If marked “time delay” or similarly, Class CC fuses are required to have a minimum opening time of 12 s when subjected to a load of two times rated current. Class CC fuses have a rejection feature (knob on fuse ferrule). Class CC fuseholders accommodate this rejection features, but reject other fuses with similar dimensions. Class CC fuses are available in one body size (0 A to 30 A).

Class CC fuses are also tested at various short-circuit levels up to their maximum interrupting rating and for compliance with prescribed maximum values of threshold current, peak let-through current, and I^2t at fault current levels of 50 000 A, 100 000 A, and 200 000 A for three ampere ranges (0 A to 15 A, 16 A to 20 A, and 21 A to 30 A), as shown in Table 6.

**Table 6—Maximum peak let-through current and clearing I^2t for Class CC fuses
(Reprinted with permission from UL)**

Current Rating I_n , A	Between threshold and 50 kA		At 100 kA		At 200 kA	
	Peak Let-through current, A	I^2t Ampere-squared seconds	Peak Let-through current, A	I^2t Ampere-squared seconds	Peak Let-through current, A	I^2t Ampere-squared seconds
0 - 15	3,000	2,000	3,000	2,000	4,000	3,000
16 - 20	3,000	2,000	4,000	3,000	5,000	3,000
21 - 30	6,000	7,000	7,500	7,000	12,000	7,000

5.3.3.7 Class G

UL 248-5 and CSA C22.2 No. 248.5 cover Class G fuses. Class G fuses are labeled as “current-limiting,” and have an ac rating to interrupt 100 000 A rms. Class G fuses have an ac voltage rating of 480 V (25 A to 60 A) and 600 V (0 A to 20 A), and may have an additional optional dc rating up to 480 V. Class G fuses may be either fast-acting or time-delay. If marked *time delay* or similarly, Class G fuses are required to have a minimum opening time of 12 s when subjected to a load of two times rated current.

Class G fuses are also tested at a short-circuit level up to their maximum interrupting rating and for compliance with prescribed maximum values of threshold current, peak let-through current, and I^2t at fault current levels of 100 000 A for each body size (0 A to 15 A, 20 A, 25 A and 30 A, and 35 A to 60 A). Class G fuses have additional maximum peak let-through current, and I^2t values at a fault current of 100 000 A for intermediate ampere ratings, as shown in Table 7.

**Table 7—Maximum peak let-through current and clearing I^2t (at 100 kA) for Class G fuses
(Reprinted with permission from UL)**

Current rating I_n , A	Peak let-through current, A	I^2t , ampere-squared seconds
1	1,000	800
3	1,500	1,200
6	2,000	1,800
10	3,000	2,800
15	4,000	3,800
20	5,000	5,000
25	6,000	6,000
30	7,000	7,000
35	8,000	14,000
40	8,500	17,000
45	9,000	18,500
50	9,500	21,000
60	10,500	25,000

5.3.3.8 Class CF

UL 248-17 cover Class CF fuses. Class CF fuses are labeled as “current-limiting” and have an ac rating to interrupt 200 000 A rms (300 000 A rms is optional). Class CF fuses have ampere ratings up to 100 A and an ac voltage rating of 600 V. Class CF fuses may have an additional optional dc rating up to 600 V. Class CF fuses may be either fast-acting or time-delay. If marked “time delay” or similarly, Class CF fuses are required to have a minimum opening time of 10 s when subjected to a load of five times rated current.

Class CF fuses are also tested at various short-circuit levels up to their maximum interrupting rating and for compliance with prescribed maximum values of threshold current, peak let-through current, and I^2t at fault current levels of 50 000 A, 100 000 A, 200 000 A, and 300 000 A for each body size (0 A to 30 A, 31 A to 60 A, 61 A to 100 A). The maximum peak let-through currents for each body size are also expressed by equations in order to determine the peak let-through current at intermediate values of fault currents. Class CF fuses have additional maximum peak let-through current and I^2t values at a fault current of 100 000 A for intermediate ampere ratings as shown in Table 8. Note that the maximum values of peak let-through current and I^2t for Class CF fuses are the same as that required for Class J fuses.

**Table 8—Maximum peak let-through current and clearing I^2t for Class CF fuses
(Reprinted with permission from UL)**

Current rating I_n , A	Between threshold and 50 kA		At 100 kA		At 200 kA		At 300 kA		Peak Let-Through Function
	Peak let-through current, A	I^2t , ampere-squared seconds	Peak let-through current, A	I^2t , ampere-squared seconds	Peak let-through current, A	I^2t , ampere-squared seconds	Peak let-through current, A	I^2t , ampere-squared seconds	
1			1,000	800					
3			1,500	1,200					
6			2,300	2,000					
10			3,300	3,000					
15			4,000	4,000					
20			5,000	5,000					
25			6,000	5,500					
30	6,000	7,000	7,500	7,000	12,000	7,000	18,500	8,400	$Y = 1E-07x^2 + 0.015x + 5000$
35			7,500	12,000					
40			8,000	17,000					
45			8,500	18,000					
50			9,000	22,000					
60	8,000	30,000	10,000	30,000	16,000	30,000	24,367	36,000	$Y = 1E-07x^2 + 0.02x + 6666.7$
70			11,500	50,000					
80			12,500	60,000					
90			13,500	75,000					
100	12,000	60,000	14,000	80,000	20,000	80,000	28,367	96,000	$Y = 1E-07x^2 + 0.02x + 10667$

Within each body size, the width of the fuse blades provides an additional level of rejection. The width of the blade varies from 1 A to 15 A, 17.5 A to 20 A, 25 A to 30 A, 35 A to 40 A, 45 A to 50 A, 60 A, 70 A, 80 A to 90 A, and 100 A. When used with fuse switches that accommodate these breaks, ampacity rejection for branch circuits is obtained.

5.3.3.9 Class CD

UL 248-18 covers Class CD fuses. Class CD fuses are labeled as “current-limiting,” and have an ac rating to interrupt 200 000 A rms. Class CD fuses have ampere ratings up to 60 A and an ac voltage rating of 600 V. Class CD fuses have an additional optional dc rating up to 250 V. Class CD fuses are time-delay fuses. If marked “time delay” or similarly, Class CD fuses are required to have a minimum opening time of 12 s when subjected to a load of two times rated current. Class CD has corresponding fuseholders. Class CD fuses are available in one body size (35 A to 60 A).

Class CD fuses are also tested at various short-circuit levels up to their maximum interrupting rating and for compliance with prescribed maximum values of threshold current, peak-let-through current, and I^2t at fault current levels of 50 000 A, 100 000 A, and 200 000 A for one ampere range (31 A to 60 A) as shown in Table 9.

**Table 9—Maximum peak let-through current and clearing I^2t for Class CD fuses
(Reprinted with permission from UL)**

Current rating I_n , A	Between threshold and 50 kA		At 100 kA		At 200 kA	
	Peak let-through current, A	I^2t , ampere-squared seconds	Peak let-through current, A	I^2t , ampere-squared seconds	Peak let-through current, A	I^2t , ampere-squared seconds
31 – 60	8,000	30,000	10,000	30,000	16,000	30,000

5.3.3.10 Class C

UL 248-2 and CSA C22.2 No. 248.2 cover Class C fuses. Class C fuses have an ac rating to interrupt 200 000 A rms. Class C fuses may be marked “current-limiting” if a threshold current test is passed. Class C fuses have ampere ratings up to 1200 A and ac rating of 600 V. Class C fuses may have an additional optional dc rating up to 600 V.

Class C fuses are also tested at a short-circuit level up to their maximum interrupting rating and for compliance with prescribed maximum values of peak let-through current and I^2t at fault current levels of 200 000 A for each body size (0 A to 100 A, 101 A to 200 A, 201 A to 800 A, and 801 A to 1200 A) as shown in Table 10.

Table 10—Maximum peak let-through current and clearing I^2t (at 200 kA) for Class C fuses (Reprinted with permission from UL)

Current rating I_n , A	Peak let-through current, A	I^2t , ampere-squared seconds
0 – 30	12,000	15,000
31 – 60	20,000	60,000
61 – 100	30,000	200,000
101 – 200	40,000	750,000
201 – 400	70,000	4,000,000
401 – 600	100,000	10,000,000
601 – 800	115,000	25,000,000
801 – 1200	125,000	40,000,000

5.3.3.11 Class CA and Class CB

UL 248-3 and CSA C22.2 No. 248.3 cover Class CA and Class CB fuses. Class CA and Class CB fuses are labeled as “current-limiting” and have an ac rating to interrupt 200 000 A rms. Class CA and Class CB fuses have an ac rating of 600 V and may have an additional optional dc rating up to 600 V. Class CA fuses are available up through 30 A and have mounting holes in their end blades. Class CB fuses are available up through 60 A, without mounting holes in their end blades.

Class CA and Class CB fuses are also tested at a short-circuit level up to their maximum interrupting rating and for compliance with prescribed maximum values of peak let-through current and I^2t at fault current levels of 200 000 A, as shown in Table 11.

Table 11 —Maximum peak let-through current and clearing I^2t (at 200 kA) for Class CA and Class CB fuses (Reprinted with permission from UL)

Class and current rating I_n	Peak let-through current,	I^2t , ampere-squared seconds
A	A	
Class CA	8,000	6,000
Class CB		
1 – 30	10,000	10,000
31 – 60	15,000	60,000

5.3.4 Supplementary overcurrent protective devices

5.3.4.1 Cable limiters

UL 248-1 and CSA C22.2 No. 248.1 are used where cable limiters are listed. Cable limiters are typically used to provide short-circuit protection of service conductors and equipment. Cable limiters are selected based on cable size, material, and termination type. Cable limiters are permitted to be applied on the supply side of the service disconnect per NEC 230.82 (NFPA 70-2017) and often used to isolate faults in service conductors where multiple conductors per phase are required.

5.3.4.2 Semiconductor (high speed) fuses

UL 248-13 and CSA C22.2 No. 248.13 cover semiconductor (also known as *high speed*) fuses. Semiconductor fuses can have ac or dc interrupting ratings up to 200 000 A, voltage ratings up to 2 000 V, and be marked “current limiting” provided that they meet the threshold ratio specified by the manufacturer. Semiconductor fuses can be either full (overload and short-circuit) or partial (short-circuit only) range. This standard does not contain requirements for a range of ampere ratings, overload performance, or dimensions, therefore, these fuses are not considered branch circuit fuses. However, NEC 430.52(C)(5) (NFPA 70) allows high speed fuses to be used for short-circuit protection on motor circuits utilizing power electronic devices. To be used in this application, a marking for replacement fuses must be provided adjacent to the fuses. High speed fuses are very current-limiting fuses that are needed for the proper protection of power electronic equipment.

5.3.4.3 Supplemental fuses

UL 248-14 and CSA C22.2 No. 248.14 cover glass, miniature, micro, and other miscellaneous fuses for supplementary overcurrent protection. These standards do not pertain to branch circuit fuses.

5.3.5 Test limiters (umbrella fuses)

UL 248-16 and CSA C22.2 No. 248.16 cover test limiters, otherwise known as *umbrella fuses*. A test limiter is used for testing purposes of equipment to represent a specific ampere rating and class of fuse available from any manufacturer. Test limiters are required to be calibrated to the maximum I_p and I^2t limits for the specific ampere rating and class of fuse. Test limiters are required to be marked with the fuse class it represents, ampere rating, voltage rating, assigned test current rating, and the words “THIS IS NOT A FUSE.”

5.4 NEMA FU-1

NEMA FU-1 covers low-voltage fuses with requirements that are similar to the requirements found in UL and CSA standards. Per Article 100 of the NEC (NFPA 70), overcurrent devices, such as fuses, are defined as either branch circuit overcurrent protective devices or supplementary overcurrent protective devices. Branch circuit overcurrent protective devices can be used for protection of a service, feeder, or branch circuit of an electrical system. Supplementary overcurrent protective devices are not permitted to be used as a substitute or in place of a branch circuit overcurrent protective device per NEC 240.10 (NFPA 70-2017) and the Canadian Electrical Code (CEC) 14-114 (CSA C22.1-2018). However, in some limited applications, such as motor branch circuits, specific supplementary overcurrent protective devices, such as semiconductor (high speed) fuses, may be permitted for branch circuit short circuit and ground fault protection per the NEC (NFPA 70).

The fuse types that are branch circuit overcurrent protective devices per the NEC (NFPA 70) and CEC (CSA C22.1) include; plug fuses, Class CC, Class CD, Class CF, Class G, Class H, Class J, Class K, Class L, Class R, Class T. All of these fuses are current limiting with the exception of plug fuses and Class H fuses. There are three basic advantages of current-limiting branch circuit fuses; high interrupting rating, ease of achieving selective coordination, and increased protection of components.

Class C, Class CA, and Class CB are HRC current-limiting fuses that are only permitted to be used in Canada per the CEC (CSA C22.1). Class C fuses are only permitted to be used for overcurrent protection where overload protection is provided by other means, such as short-circuit protection of a motor circuit where overload protection is provided by an overload relay. Class CA and Class CB fuses are permitted to be used as branch circuit protective devices.

The fuse types that are supplementary overcurrent protective devices include cable limiters, semiconductor (high speed) fuses, and supplemental fuses. Cable limiters are current limiters (but not marked “current limiting”). Semiconductor (high speed) fuses may be marked “current limiting.” Supplemental fuses are not permitted to be marked “current limiting.”

Test limiters (umbrella fuses) are not intended for use in electrical distribution systems and as such are not considered either branch circuit overcurrent protective devices or supplementary overcurrent protective devices.

5.5 The NEC (NFPA 70) and CEC (CSA C22.1)

The NEC (NFPA 70) and CEC contain requirements for the application of fuses in electrical distribution systems. NEC (NFPA 70) and CEC (CSA C22.1) articles that apply to fuses include:

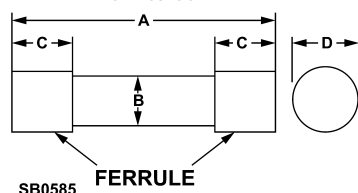
- NEC Article 100: Definition of Branch Circuit Overcurrent Protective Device
- NEC Article 100: Definition of Supplementary Overcurrent Protective Device
- NEC Article 100: Definition of Coordination, Selective (Selective Coordination)
- NEC 110.9 and CEC 14-012: Overcurrent Device Interrupting Rating Requirements
- NEC 110.10 and CEC 14-012 Appendix B: Protection of Circuit Components (Short-Circuit Current Ratings)
- NEC 110.24: Marking of Available Fault Current
- NEC 240.2: Definition of Current-Limiting Overcurrent Protective Device
- NEC 240.3: List of Articles Covering Overcurrent Protection for Specific Equipment
- NEC 240.4 and CEC 14-100, 14-104: Protection of Conductors

- NEC 240.6: Standard Ampere Ratings
- NEC 240.8 and CEC 14-112: Overcurrent Devices in Parallel
- NEC 240.10 and CEC 14-114: Supplementary Overcurrent Protection
- CEC 14-200: Use of Time-Delay and Low-Melting Point Fuses
- NEC 240.50 and CEC 14-202: Use of Plug Fuses
- NEC 240.51 and CEC 14-204: Use of Noninterchangeable (Edison Base) Fuses
- NEC 240.53: Use of Type S Fuses
- NEC 240.54: Use of Types S Fuses, Adapters, and Fuseholders
- CEC 14-208: Rating of Fuses
- CEC 14-212: Use of Fuses
- NEC 240.60(B): Use of Noninterchangeable Cartridge Fuses
- NEC 240.60(C): Marking on Fuses
- NEC 240.60(D): Renewable Fuses
- NEC 240.61: Fuse Classification
- NEC 240.86 and CEC 14-014: Series Ratings
- NEC 430.52 and CEC 28-200: Motor Branch Circuit Protection
- NEC 450.3 and CEC 26-252, 26-254, 26-256: Transformer Protection
- NEC 517.30(G): Coordination of Essential Electrical Systems
- NEC 620.62 and CEC 38-062: Selective Coordination of Elevator Circuits
- NEC 695.3(C)(3): Selective Coordination of Multibuilding Campus-Style Complexes
- NEC 700.32 and CEC 46-206: Selective Coordination of Emergency Systems
- NEC 701.27: Selective Coordination of Legally Required Standby Systems
- NEC 708.54: Selective Coordination of Critical Operation Power Systems

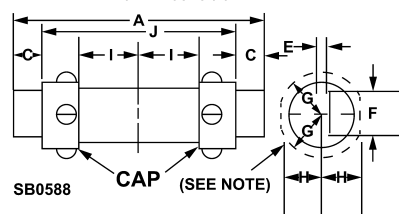
6. Standard dimensions

UL and CSA have established the dimensional requirements for the various classifications of low-voltage fuses. Figure 4 through Figure 12 show typical dimensions (see fuse manufacturer's data for actual dimensions) for Class CC, Class CD (UL), and Class CF (UL), Class G, Class H, Class J, Class K, Class L, Class R, and Class T.

**FERRULE-TYPE CARTRIDGE FUSE —
0 A to 60 A**



**KNIFE-BLADE TYPE CARTRIDGE FUSE —
61 A to 600 A**



NOTE—The dashed line represents the limit of the maximum projection of a screw, rivet head, or the like. It becomes a circle for a fuse rated more than 200.

A. DIMENSIONS OF KNIFE-BLADE TYPE FUSES IN INCHES (mm)

Rating		Overall Length of Fuse ^a	Maximum Outside Diameter of Tube	Minimum Length of Ferrule or Blade	Outside Diameter of Ferrule ^b	Thickness of Blade ^c	Width of Blade ^d	Maximum Dimensions over Projections ^e		Minimum Distance from Midpoint of Fuse to Nearest Live Part	Minimum Overall Length of Cylindrical Body ^f
								Measured Parallel to Blade	Measured at Right Angles to Blade		
Volts	Amperes	A	B	C	D	E	F	G	H	I	J
250	0–30	2.00 (50.8)	0.53 (13.5)	0.50 (12.7)	0.562 (14.27)						
	31–60	3.00 (76.2)	0.78 (19.8)	0.625 (15.9)	0.812 (20.62)						
	61–100	5.87 (149.2)		1.00 (25.4)		0.125 (3.18)	0.750 (19.05)	0.66 (16.7)	0.59 (15.1)	1.03 (26.2)	
	101–200	7.12 (181.0)		1.37 (34.9)		0.188 (4.78)	1.125 (28.58)	0.94 (23.8)	0.84 (21.4)	1.19 (30.2)	4.12 (104.8)
	201–400	8.62 (291.1)		1.87 (47.6)		0.250 (6.35)	1.625 (41.28)	1.20 (30.6)	1.20 (30.6)	1.19 (30.2)	4.62 (117.5)
	401–600	10.37 (263.5)		2.25 (57.1)		0.250 (6.35)	2.000 (50.80)	1.45 (36.9)	1.45 (36.9)	1.53 (38.9)	5.19 (131.8)
600	0–30	5.00 (127.0)	0.78 (19.8)	0.50 (12.7)	0.812 (20.62)						
	31–60	5.50 (139.7)	1.03 (26.2)	0.62 (15.9)	1.062 (26.97)						
	61–100	7.87 (200.0)		1.00 (25.4)		0.125 (3.18)	0.750 (19.05)	0.78 (19.8)	0.72 (18.3)	1.75 (44.4)	
	101–200	9.62 (244.5)		1.37 (34.9)		0.188 (4.78)	1.125 (28.58)	1.06 (27.0)	0.98 (25.0)	2.25 (57.1)	6.12 (155.6)
	201–400	11.62 (295.3)		1.87 (47.6)		0.250 (6.35)	1.625 (41.28)	1.45 (36.9)	1.45 (36.9)	2.50 (63.5)	7.12 (181.0)
	401–600	13.37 (339.7)		2.25 (57.1)		0.250 (6.35)	2.000 (50.80)	1.72 (43.7)	1.72 (43.7)	2.69 (68.3)	8.18 (208.0)

^aTolerances: 0 A to 60 A, ± 0.03 in (± 0.8 mm); 61 A to 200 A, ± 0.06 in (± 1.6 mm); 201 A to 600 A, ± 0.09 in (± 2.4 mm).

^bColumn D tolerance: ± 0.020 in (± 0.020 mm).

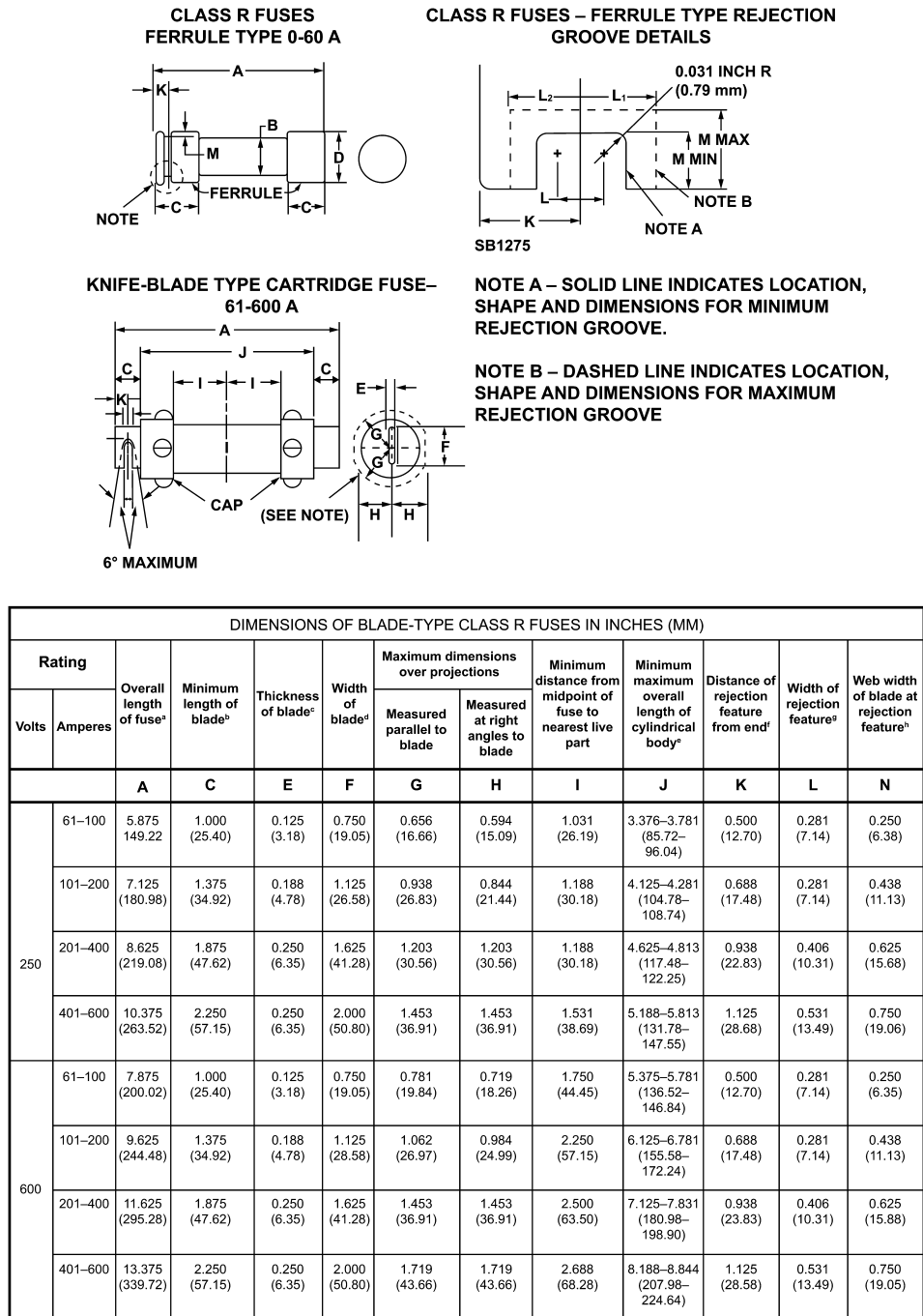
^cColumn E tolerance: ± 0.003 in (± 0.08 mm).

^dColumn F tolerance: ± 0.035 in (± 0.89 mm).

^eThe maximum overall dimension of a screw ring for a renewable fuse, the position of which with respect to the position of the knife blade cannot be predetermined, shall be no more than the value specified for dimension H.

^fThe length of the cylindrical body may be less than the indicated value if other acceptable interference means, pins through the blades collars, and the like, are provided to prevent mounting the fuse in a fuseholder that will accommodate a fuse rated in the next lower bracket of current ratings.

**Figure 4—Class H and Class K fuse dimensions
(Reprinted with permission from UL)**



^aTolerances: 61–200 A, ± 0.062 in (± 1.57 mm); 201–600 A, ± 0.094 in (± 2.39 mm).

^bThe length of one blade shall not be more than 0.062 in (1.57 mm) longer than the other blade.

^cColumn E tolerance: ± 0.003 in (0.08 mm).

^dColumn F tolerance: ± 0.035 in (0.89 mm).

^eThe length of the cylindrical body may be less than the indicated value if other acceptable interference means (pins through the blades, collars, or the like) are provided to prevent mounting the fuse in a fuseholder that will accommodate a fuse rated in the next lower bracket of current rating.

^fColumn K tolerance: ± 0.008 in (± 0.20 mm).

^gColumn L tolerance: -0.005 , $+0.025$ in (-0.13 , $+0.64$ mm). Dimension is diameter of slot at semicircle. Maximum rounding of corner at end of slot 0.125 in (3.18 mm) radius.

^hColumn N tolerance: ± 0.031 in (± 0.79 mm).

**Figure 5—Class R fuse dimensions
(Reprinted with permission from UL)**

DIMENSIONS OF FERRULE-TYPE CLASS R FUSES IN INCHES (MM)										
Rating		Overall length of fuse ^a	Maximum outside diameter of tube	Minimum length of ferrule	Outside diameter of ferrule ^b	Distance of rejection feature from end ^c	Minimum width of rejection feature ^d	Minimum–maximum depth of rejection feature	Maximum width toward end	Maximum width toward body
Volts	Amperes									
		A	B	C	D	K	L	M	L ₂	L ₁
250	0–30	2.000 (50.80)	0.531 (13.49)	0.500 (12.70)	0.562 (14.27)	0.156 (3.96)	0.070 (1.78)	0.085–0.130 (2.16–3.30)	0.115 (2.92)	0.150 (3.81)
	31–60	3.000 (72.60)	0.781 (19.84)	0.625 (15.88)	0.812 (20.62)	0.188 (4.78)	0.086 (2.18)	0.085–0.130 (2.16–3.30)	0.123 (3.12)	0.170 (4.32)
600	0–30	5.000 (127.00)	0.781 (19.84)	0.500 (12.70)	0.812 (20.62)	0.188 (4.78)	0.086 (2.18)	0.085–0.130 (2.16–3.30)	0.123 (3.12)	0.170 (4.32)
	31–60	5.500 (139.70)	1.031 (26.19)	0.625 (15.88)	1.062 (26.97)	0.250 (6.35)	0.086 (2.18)	0.085–0.130 (2.16–3.30)	0.154 (3.91)	0.180 (4.57)

^aColumn A tolerance: ± 0.031 in (± 0.79 mm).

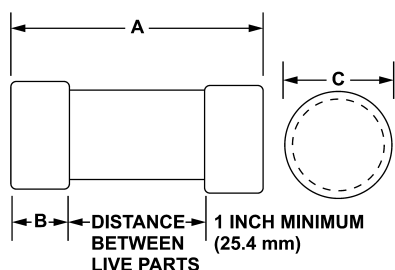
^bColumn D tolerance: ± 0.008 in (± 0.20 mm). To provide proper contact, the diameter of rejection ferrule end shall be equal to or not more than 0.050 in (1.27 mm) smaller than actual diameter of main contact area for any fuse, and no part of rejection ferrule end shall protrude beyond the diameter of the main part of the ferrule.

^cColumn K tolerance: $+0.008$, -0.016 in ($+0.20$, -0.41 mm).

^dDimension column L: Distance between centers of 0.031 in (0.79 mm) radius fillets. Shape of rejection groove is not specified but shall be completely within solid and dashed lines regardless of shape.

Figure 5—Class R fuse dimensions (*continued*) (Reprinted with permission from UL)

FERRULE-TYPE CLASS J FUSES —
0 A to 60 A

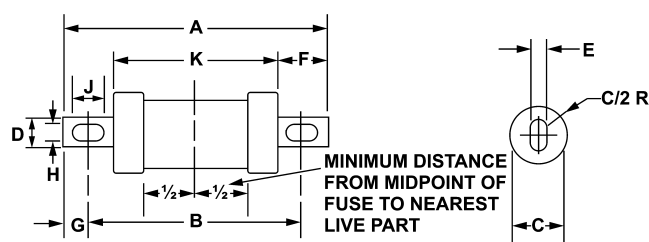


DIMENSIONS OF FERRULE-TYPE CLASS J FUSES IN INCHES (mm)^a

Cartridge Size in Amperes	Overall Length	Minimum Length of Ferrule	Outside Diameter of Ferrule
	A	B	C
0–30	2.25 (57.1)	0.50 (12.7)	0.812 (20.62)
31–60	2.37 (60.3)	0.63 (15.9)	1.062 (26.97)

^aTolerances: A, ± 0.03 in (± 0.8 mm); C, ± 0.008 in (± 0.20 mm).

KNIFE-BLADE TYPE CLASS J FUSES—61 A to 200 A



DIMENSIONS OF KNIFE-BLADE TYPE CLASS J FUSES IN INCHES (mm)^a

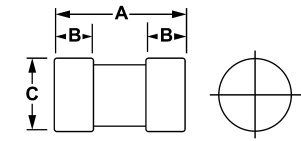
Cartridge Size in Amperes	Overall Length	Distance Between Centers of Slot	Maximum Diameter ^b	Width of Blades	Thickness of Blades	Length of Blades	Distance from End of Blade to Center of Slot	Width of Slot	Length of Slot	Length of Tube
	A	B	C	D	E	F	G	H	J	K
61–100	4.62 (117.5)	3.62 (92.1)	1.13 (28.6)	0.750 (19.05)	0.125 (3.18)	1.00 (25.4)	0.50 (12.7)	0.281 (7.14)	0.375 (9.52)	2.62 (66.7)
101–200	5.75 (146.0)	4.38 (111.1)	1.63 (41.3)	1.125 (28.58)	0.188 (4.78)	1.37 (34.9)	0.69 (17.5)	0.281 (7.14)	0.375 (9.52)	3.00 (76.2)
201–400	7.12 (181.0)	5.25 (133.4)	2.13 (54.0)	1.625 (41.28)	0.250 (6.35)	1.87 (47.6)	0.94 (23.8)	0.406 (10.32)	0.531 (13.49)	3.37 (85.7)
401–600	8.00 (203.2)	6.00 (152.4)	2.63 (66.7)	2.000 (50.80)	0.375 (9.52)	2.12 (54.0)	1.00 (25.4)	0.531 (13.49)	0.688 (17.48)	3.75 (95.2)

Tolerances: A, ± 0.09 in (± 2.4 mm); B, ± 0.06 in (± 1.6 mm); D, ± 0.035 in (± 0.89 mm); E, ± 0.003 in (± 0.08 mm); F, ± 0.03 in (± 0.8 mm); G, ± 0.03 in (± 0.8 mm); H, ± 0.005 in (± 0.13 mm); J, plus 0.062, minus 0.000 in (plus 1.57 mm, minus 0.00 mm); K, ± 0.03 in (± 0.8 mm).

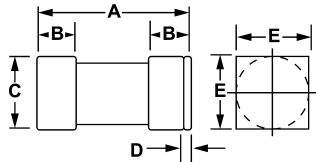
C/2 includes maximum dimension over projection.

**Figure 6—Class J fuse dimensions
(Reprinted with permission from UL)**

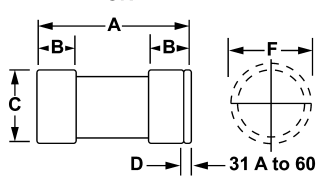
DIMENSIONS OF FERRULE-TYPE FUSES IN INCHES (mm)



0 A to 60 A 300 V
0 A to 30 A 600 V



OR



31 A to 60 A 600 V

Rating		Overall Length of Fuse ^a	Length of Ferrule ^b	Outside Diameter of Ferrule ^c	Thickness of Rejection Feature ^d	Width of Rejection Feature ^{d,e}	Diameter of Rejection Feature ^{d,f}
Volts	Amperes	A	B	C	D	E	F
300	0–30	0.880 (22.35)	0.280 (7.11)	0.406 (10.31)	—	—	—
		0.880 (22.35)	0.280 (7.11)	0.563 (14.30)	—	—	—
	31–60	1.500 (38.10)	0.280 (7.11)	0.563 (14.30)	—	—	—
		1.560 (39.62)	0.410 (10.41)	0.812 (20.62)	0.062 (1.57)	0.812 (20.62)	0.994 (25.25)

^aTolerances: 0 A to 60 A, 300 V, ± 0.020 in (± 0.51 mm); 0 A to 60 A, 600 V, ± 0.40 in (± 1.02 mm).

^bColumn B tolerance: ± 0.020 in (± 0.51 mm).

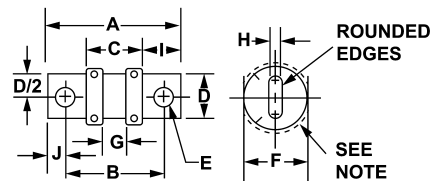
^cColumn C tolerance: ± 0.006 in (± 0.15 mm). Diameter of tube is less than ferrules.

^dColumns D and E tolerance: ± 0.006 in (± 0.15 mm).

^eRejection feature may be either square or round.

^fColumn F tolerance: minus 0.006 in plus 0.016 in (minus 0.15 mm plus 0.41 mm).

KNIFE-BLADE TYPE FUSES



SB 1284

DIMENSIONS OF KNIFE-BLADE TYPE FUSES IN INCHES (mm)

Rating		Overall Length of Fuse ^a	Distance Between Mounting Centers ^b	Maximum Length of Body	Width of Blade ^c	Diameter of Mounting Holes ^d	Maximum Diameter of Fuse	Minimum Length of Insulated Body	Thickness of Blade ^e	Minimum Length of Blade	Distance of Mounting Holes from End ^f
Volts	Amperes	A	B	C	D	E	F	G	H	I	J
300	61–100	2.156 (54.76)	1.556 (39.52)	0.850 (21.59)	0.750 (19.05)	0.281 (7.14)	0.828 (21.03)	0.250 (6.35)	0.125 (3.18)	0.646 (16.41)	0.300 (7.62)
		2.438 (61.93)	1.895 (48.05)	0.850 (21.59)	0.875 (22.22)	0.344 (8.74)	1.078 (27.38)	0.250 (6.35)	0.188 (4.78)	0.787 (19.99)	0.372 (9.45)
	101–200	2.750 (69.85)	1.844 (46.84)	0.860 (21.84)	1.000 (25.40)	0.406 (10.31)	1.344 (34.14)	0.250 (6.35)	0.250 (6.35)	0.926 (23.52)	0.453 (11.51)
		3.063 (77.80)	2.031 (51.59)	0.880 (22.35)	1.250 (31.75)	0.484 (12.29)	1.625 (41.28)	0.250 (6.35)	0.312 (7.92)	1.074 (27.28)	0.516 (13.11)
	201–400	3.375 (85.73)	2.219 (56.36)	0.891 (22.63)	1.750 (44.45)	0.547 (13.89)	2.078 (52.78)	0.250 (6.35)	0.375 (9.53)	1.222 (31.04)	0.578 (14.68)
		4.000 (101.6)	2.531 (64.29)	1.078 (27.38)	2.000 (50.8)	0.609 (15.48)	2.516 (63.90)	0.250 (6.35)	0.438 (11.11)	1.441 (36.60)	0.735 (18.67)
	401–600	2.953 (75.01)	2.352 (59.74)	1.640 (41.66)	0.750 (19.05)	0.281 (7.14)	0.828 (21.03)	0.500 (12.70)	0.125 (3.18)	0.646 (16.41)	0.300 (7.62)
		3.250 (82.55)	2.507 (63.67)	1.660 (42.16)	0.875 (22.22)	0.344 (8.74)	1.078 (27.38)	0.500 (12.70)	0.188 (4.78)	0.787 (19.99)	0.372 (9.45)
600	201–400	3.625 (92.08)	2.719 (69.06)	1.730 (43.94)	1.000 (25.40)	0.406 (10.31)	1.625 (41.28)	0.500 (12.70)	0.250 (6.35)	0.926 (23.52)	0.453 (11.51)
		3.984 (101.19)	2.953 (75.01)	1.780 (45.21)	1.250 (31.75)	0.484 (12.29)	2.094 (53.19)	0.500 (12.70)	0.312 (7.92)	1.074 (27.28)	0.516 (13.11)
	401–600	4.328 (109.93)	3.172 (80.57)	1.875 (47.63)	1.750 (44.45)	0.547 (13.89)	2.516 (63.91)	0.500 (12.70)	0.375 (9.53)	1.207 (30.66)	0.578 (14.68)

^aTolerances: 61 A to 200 A, 300 V, ± 0.020 in (± 0.51 mm); 201 A to 1200 A, 300 V and 61 A to 800 A, 600 V, ± 0.40 in (± 1.02 mm).

^bColumn B tolerance: ± 0.015 in (± 0.38 mm).

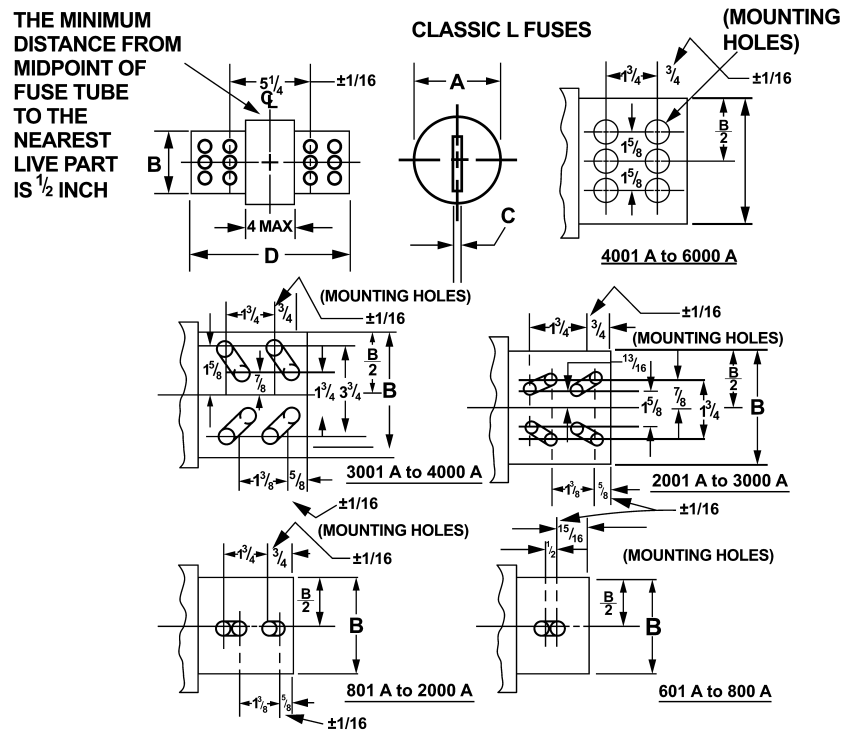
^cColumns D and J tolerance: ± 0.020 in (± 0.51 mm), except J tolerance, ± 0.028 in (± 0.71 mm) for 801 A to 1200 A, 300 V.

^dTolerances: minus 0.000 in (minus 0.00 mm); 61 A to 100 A, plus 0.005 in (plus 0.13 mm); 101 A to 200 A, plus 0.006 in (plus 0.15 mm);

210 A to 400 A, plus 0.007 in (plus 0.18 mm); 401 A to 1200 A, plus 0.008 in (plus 0.20 mm).

^eColumn H tolerance: ± 0.006 in (± 0.15 mm).

Figure 7—Class T fuse dimensions
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ALL DIMENSIONS ARE IN INCHES

ALL TOLERANCES ARE $\pm 1/64$ INCH UNLESS OTHERWISE NOTED

$5/8 \pm 1/32$ INCH SLOTS OR HOLES MAY BE USED. SHADED HOLES INDICATE DRILLING REQUIRED FOR CLASS "L" FUSE MOUNTING.

Inches	1/64	1/32	1/16	1/2	5/8	3/4	13/16	7/8	15/16	1 3/8	1 5/8	1 3/4	3 1/4	4	5 3/4
mm	0.4	0.8	1.6	12.7	15.9	19.0	20.6	22.2	23.8	34.9	41.3	44.4	82.6	101.6	146.0

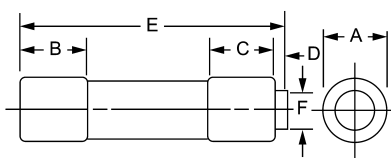
DIMENSIONS OF CLASS L FUSES IN INCHES (mm)^a

Cartridge Size in Amperes	Maximum Diameter	Width of Blades	Thickness of Blades	Overall Length
	A	B	C	D
601–800	2.53 (64.3)	2.0 (50.8)	0.375 (9.5)	8.63 (219.1)
801–1200	2.78 (70.6)	2.0 (50.8)	0.375 (9.5)	10.75 (273.0)
1201–1600	3.03 (77.0)	2.38 (60.3)	0.44 (11.1)	10.75 (273.0)
1601–2000	3.53 (89.7)	2.75 (69.8)	0.50 (12.7)	10.75 (273.0)
2001–2500	5.03 (127.8)	3.50 (88.9)	0.75 (19.0)	10.75 (273.0)
2501–3000	5.03 (127.8)	4.0 (101.6)	0.75 (19.0)	10.75 (273.0)
3001–4000	5.78 (146.8)	4.75 (120.6)	0.75 (19.0)	10.75 (273.0)
4001–5000	7.16 (181.8)	5.25 (133.4)	1.0 (25.4)	10.75 (273.0)
5001–6000	7.16 (181.8)	5.75 (146.0)	1.0 (25.4)	10.75 (273.0)

^aTolerances: B, ± 0.06 in (± 1.6 mm); C, ± 0.03 in (± 0.8 mm); D, ± 0.09 in (± 2.4 mm).

**Figure 8—Class L fuse dimensions
(Reprinted with permission from UL)**

CLASS CC FUSE



DIMENSIONS OF CLASS CC FUSES IN INCHES (mm)

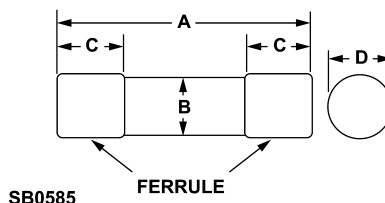
Rating		Ferrule Diameter ^a	Ferrule Length ^a	Ferrule Length ^a	Rejection Length ^a	Overall Length ^b	Rejection Diameter ^a
Volts	Amperes	A	B	C	D	E	F
600	0–30	0.405 (10.29)	0.375 (9.53)	0.375 (9.53)	0.125 (3.18)	1.500 (38.10)	0.250 (6.35)

^aTolerance: ± 0.005 in (± 0.13 mm).

^bTolerance: ± 0.31 in (± 0.79 mm).

Figure 9—Class CC fuse dimensions
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CLASS G FUSES

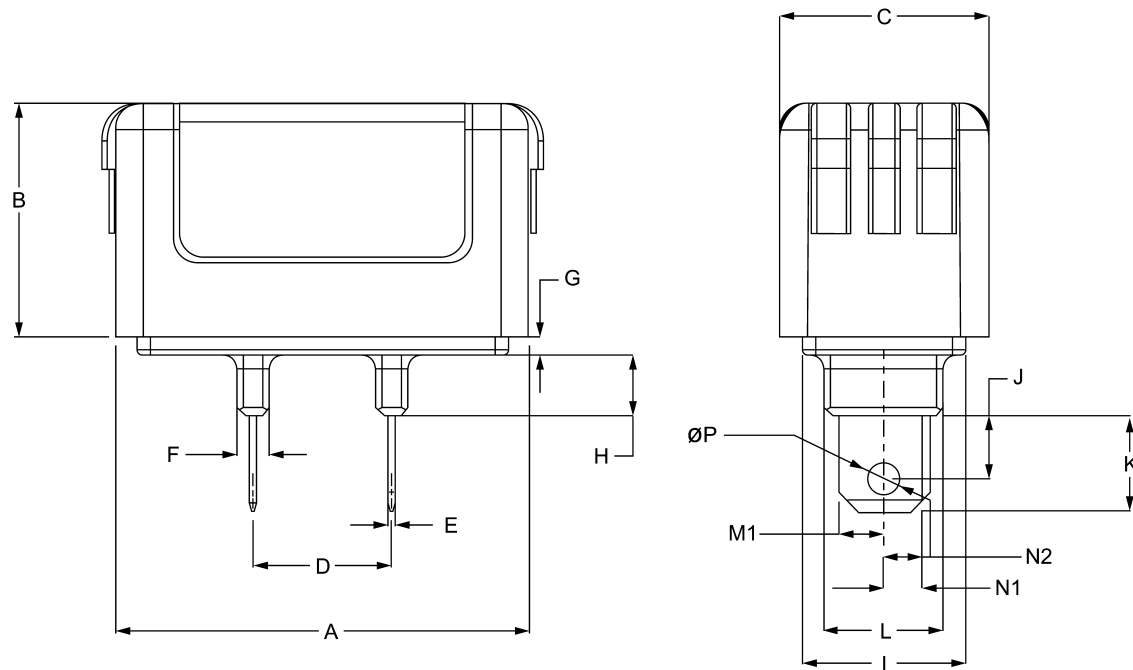


DIMENSIONS OF CLASS G FUSES IN INCHES (mm)^a

Rating		Overall Length of Fuse	Maximum Outside Diameter of Tube	Minimum Length of Ferrule	Outside Diameter of Ferrule
Volts	Amperes	A	B	C	D
300	0–15	1.31 (33.3)	0.38 (9.5)	0.28 (7.1)	0.406 (10.31)
300	16–20	1.41 (35.7)	0.38 (9.5)	0.28 (7.1)	0.406 (10.31)
300	21–30	1.62 (41.3)	0.38 (9.5)	0.28 (7.1)	0.406 (10.31)
300	31–60	2.25 (57.1)	0.38 (9.5)	0.50 (12.7)	0.406 (10.31)

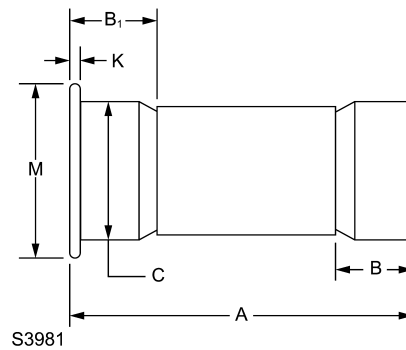
^aTolerance: A, ± 0.03 in (± 0.8 mm); D, ± 0.006 in (± 0.15 mm).

Figure 10—Class G fuse dimension
(Reprinted with permission from UL)



Fuse Ampacity										
DIM (in)	Tolerance	1 A to 15 A	17.5 A to 20 A	25 A to 30 A	35 A to 40 A	45 A to 50 A	60 A	70 A	80 A to 90 A	100 A
A	±0.005	1.750	1.750	1.750	2.000	2.000	2.000	2.882	2.882	2.882
B	±0.005	1.000	1.000	1.000	1.125	1.125	1.125	1.260	1.260	1.260
C	±0.005	0.750	0.750	0.750	1.000	1.000	1.000	1.000	1.000	1.000
D	±0.005	0.667	0.667	0.667	0.667	0.667	0.667	0.645	0.645	0.645
E	±0.005	0.040	0.040	0.040	0.040	0.040	0.040	0.063	0.063	0.063
F	±0.005	0.160	0.160	0.160	0.160	0.160	0.160	0.220	0.220	0.220
G	±0.005	0.080	0.080	0.080	0.090	0.090	0.090	0.090	0.090	0.090
H	±0.005	0.200	0.200	0.200	0.290	0.290	0.290	0.290	0.290	0.290
I	±0.005	0.580	0.580	0.580	0.790	0.790	0.790	0.790	0.790	0.790
J	±0.005	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300
K	±0.005	0.458	0.458	0.458	0.465	0.465	0.465	0.533	0.533	0.533
L	±0.005	0.580	0.580	0.580	0.580	0.580	0.580	0.790	0.790	0.790
M1	±0.002	0.115	0.156	0.156	0.179	0.219	0.219	0.245	0.285	0.285
M2	±0.002	0.115	0.115	0.156	0.179	0.179	0.219	0.245	0.245	0.285
N1	±0.002	0.115	0.115	0.156	0.179	0.179	0.219	0.245	0.285	0.285
N2	±0.002	0.115	0.156	0.156	0.179	0.219	0.219	0.245	0.245	0.285
P	±0.002	0.156	0.156	0.156	0.156	0.156	0.156	0.156	0.156	0.156

**Figure 11 —Class CF (UL) fuse dimensions
(Reprinted with permission from UL)**



Current rating I_n , A	Between threshold and 50 kA		At 100 kA		At 200 kA	
	Peak let-through current, A	I^2t , ampere-squared seconds	Peak let-through current, A	I^2t , ampere-squared seconds	Peak let-through current, A	I^2t , ampere-squared seconds
31–60	8000	30 000	10 000	30 000	16 000	30 000

Figure 12—Class CD (UL) fuse dimensions
(Reprinted with permission from UL)

7. Fuse performance characteristics

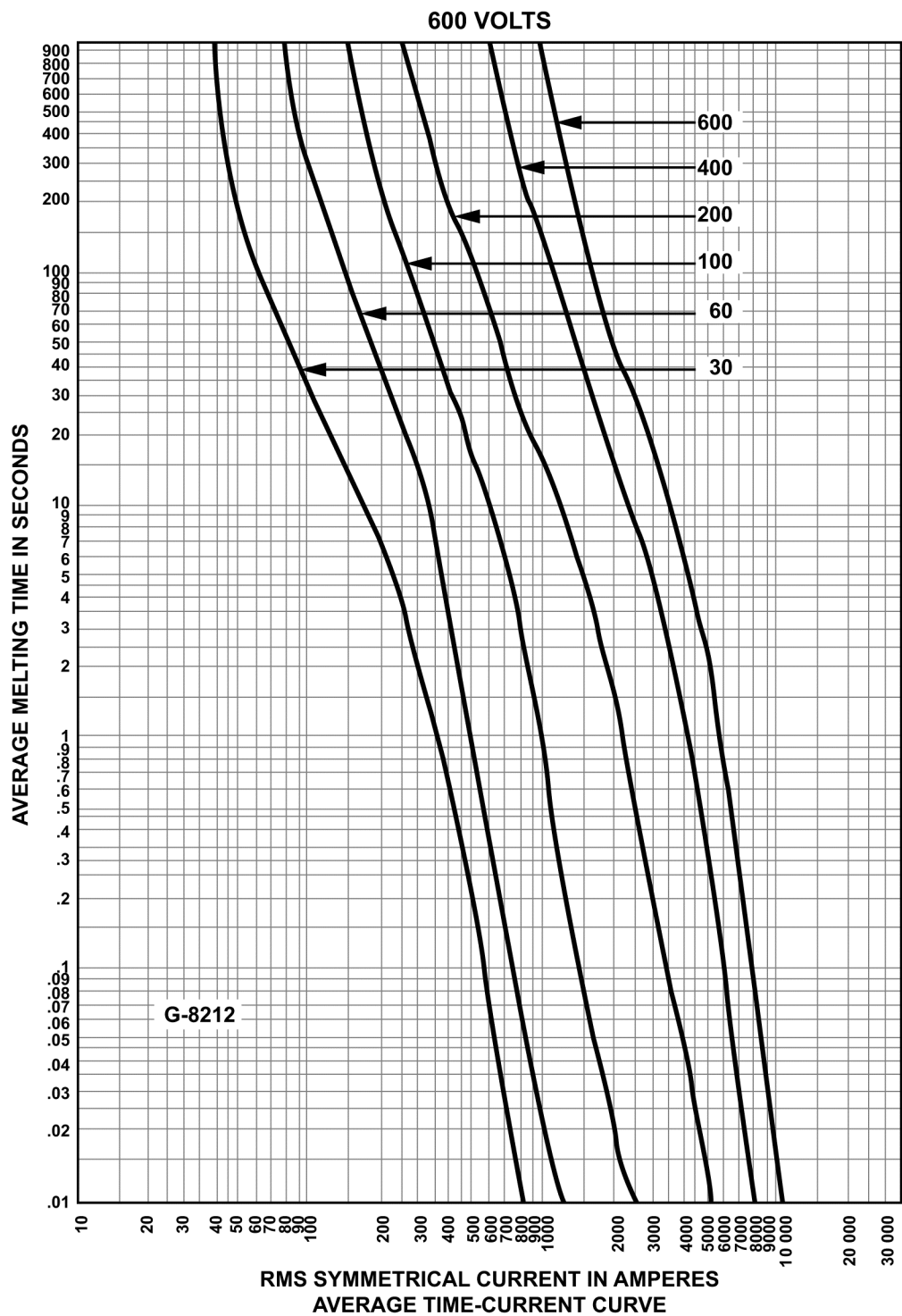
7.1 Introduction

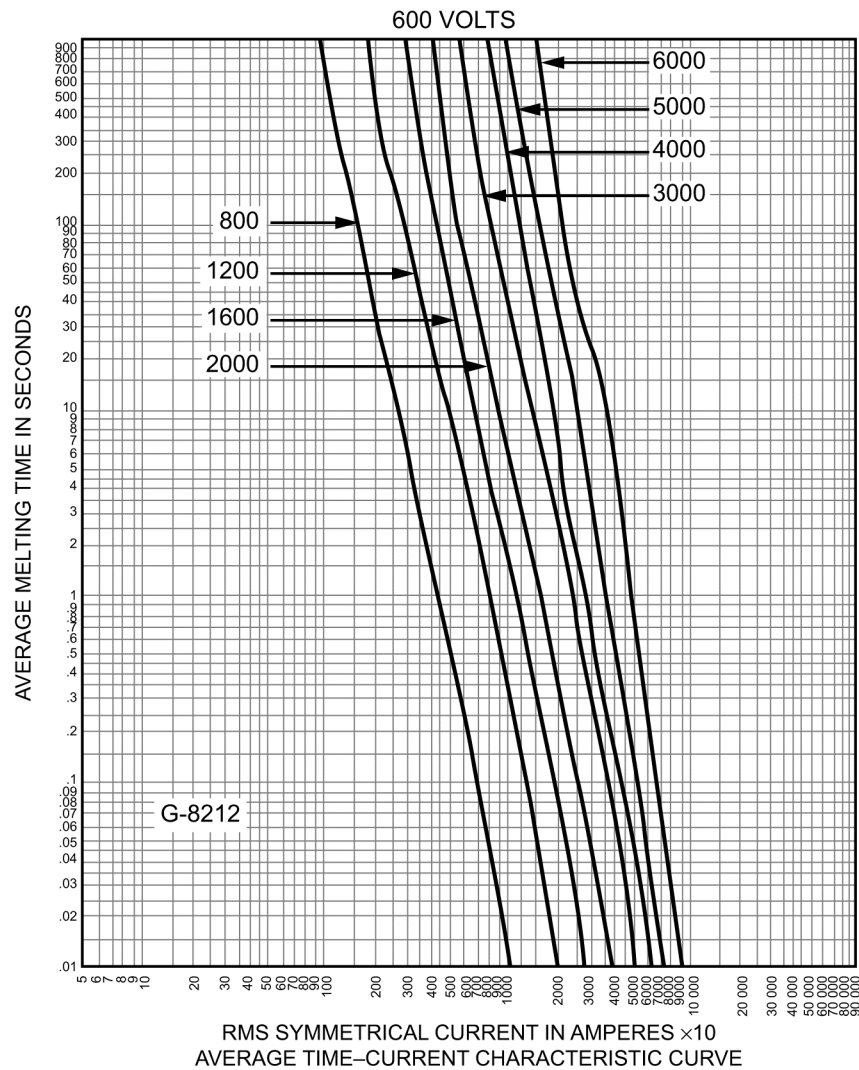
Fuse performance can be shown by two different types of charts or curves. For low-level overcurrent conditions, such as overloads (and low-level ground or arcing faults), time-current curves are utilized to show the performance of the fuses. For medium- to high-level overcurrent conditions, such as ground faults, arcing faults, and bolted faults, let-through charts are utilized.

7.2 Time-current-characteristic (TCC) curves

Time-current-characteristic curves of fuses show the relationship between various overcurrent values and their respective opening times. Time-current curves can be provided by the fuse manufacturer to electrical power system software companies or directly to the design engineer. The current values are normally represented on the abscissa (horizontal axis). The time values are shown on the ordinate (vertical axis) and may represent the minimum melting time, average melting time, or total clearing time, as specified on the curve.

The average melting time is assumed to be represented unless otherwise stated. It represents an opening characteristic having a maximum tolerance of $\pm 15\%$ in current for any given time. Thus the -15% boundary represents the minimum melting characteristic, and the $+15\%$ boundary usually represents the total clearing time. The curves in Figure 13 and Figure 14 show the average melting time characteristics for RK-5 time-delay fuses (30 A to 600 A) and Class L current-limiting fuses (800 A to 6000 A), respectively. For performance of fuses with current values greater than what is shown on the time current curves, let-through charts should be consulted as shown in 7.4.





NOTE: FOR ILLUSTRATION PURPOSES ONLY. REFER TO FUSE MANUFACTURER FOR SPECIFIC AND UP-TO-DATE DATA.

Figure 14—Time-delay, current-limiting fuses, Class L

7.3 Current-limiting characteristics

Due to the speed of response to short-circuit currents, current-limiting fuses have the ability to cut off the current before it reaches its full prospective short-circuit value. Figure 1 and Figure 2 show the current-limiting action of fuses. The available short-circuit current would flow if no fuse were in the circuit, or if a non-current-limiting protective device were in the circuit. In its current-limiting range, a current-limiting fuse limits the peak current to a value less than the available value; opens in 0.5 cycle or less in its current-limiting range; and, therefore, lets through only a portion of the available short-circuit energy. The degree of current limitation is usually represented in the form of peak let-through current charts.

7.4 Peak let-through current charts

Peak let-through current charts (sometimes referred to as current-limiting effect curves) are useful for determining the let-through current that a manufacturer-specific current-limiting fuse provides to the equipment beyond it under a short-circuit condition. These charts show fuse peak let-through current as a

function of available symmetrical rms current, as shown in Figure 15. The horizontal axis is the prospective available fault current at the fuse stated in symmetrical rms amperes. The vertical axis is marked in instantaneous peak amperes. The straight line running from the lower left to the upper right shows a 2.3 relationship (based on a 15% power factor; see UL 248-1-2011/CSA C22.2 No. 248.1-2011) between the peak current that would occur without a current-limiting device in the circuit and the available symmetrical rms current. The diagonal lines coming off this straight line represent the maximum instantaneous peak amperes the identified fuses (class and ampere rating) allow to flow based on the available symmetrical rms current. The point where the two lines meet is commonly referred to as the *current-limiting-threshold*, where the fuse starts to be current limiting for these specific fault conditions.

Peak let-through current and apparent equivalent rms let-through current can be determined from the let-through current charts and in some cases may be used to determine equipment protection. It is important to note that the peak let-through values from manufacturer-specific fuse peak let-through charts will be equal to or lower than what is required per the maximum UL and CSA peak let-through values from the appropriate fuse class.

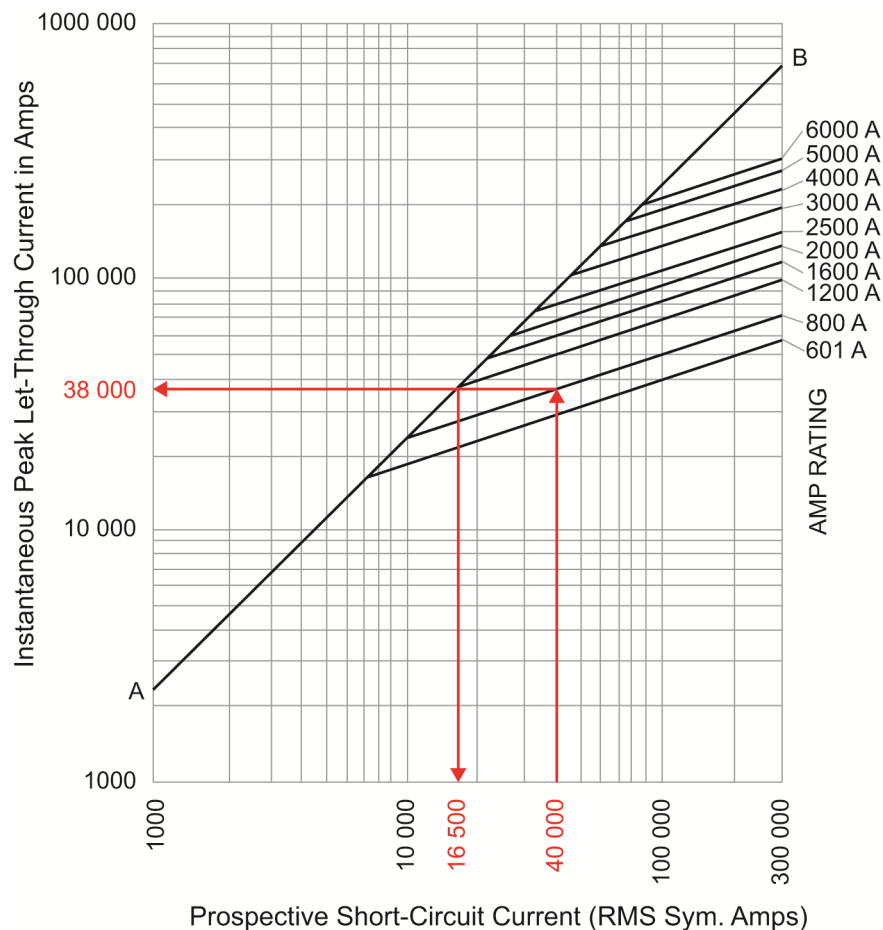
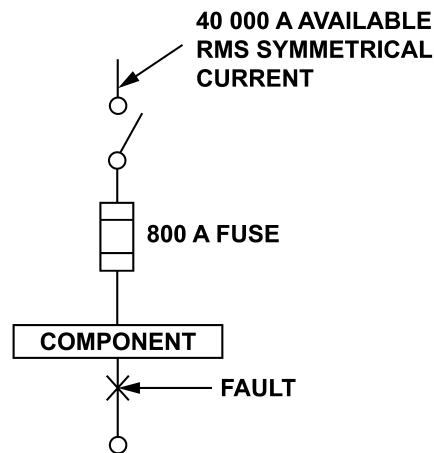


Figure 15—Typical 60 Hz peak let-through current as a function of available rms symmetrical current (15% power factor)

Let-through data may be compared to short-circuit current ratings of the fixed components that are static and have a time rating of 0.5 cycle or longer at a test circuit power factor of 15% or greater. Examples include wire, cable, and bus. An example showing the application of the let-through current charts is represented in Figure 16 where the load-side component is protected by an 800 A current-limiting fuse.



NOTE—The load-side component must remain passive during the interruption period of the upstream fuse.

Figure 16—Example of applying fuse let-through charts

Example: Determine the fuse let-through current values with 40 000 A rms symmetrical available at the line side of the fuse. Enter the let-through current chart of Figure 15 at an available current of 40 000 A rms symmetrical, and find a fuse peak let-through current of 38 000 A and an effective rms current of 16 500 A. The clearing time is less than 0.5 cycle. The load-side circuit components are not subjected to an I^2t duty greater than the total clearing let-through I^2t of the fuse.

Magnetic forces vary with the square of the peak current I_p^2 and can be severe. These forces can be reduced considerably when current-limiting fuses are used.

7.5 Maximum clearing I^2t

I^2t is a measure of the energy that a fuse lets through while clearing a fault. Every piece of electrical equipment is limited in its capability to withstand energy. The equipment I^2t withstand rating can be compared with maximum clearing I^2t values for fuses. For instance, variable frequency drive manufacturers compare the I^2t withstand of their internal semiconductor components with the I^2t clearing values of the high speed (semiconductor) fuses to determine protection of the semiconductor devices and ultimately determine the short-circuit current rating of the adjustable speed drive. These maximum clearing I^2t values for high speed (semiconductor) fuses are available from fuse manufacturers.

7.6 Arc flash protection

A key consideration for mitigating arc flash hazards is reducing the amount of current and time of the arcing event. Since current-limiting fuses are able to reduce both the let-through current and time (0.5 cycle or less), they can be an effective way to mitigate arc flash hazards when the arcing current is greater than the fuse's current-limiting threshold current. In addition, since testing and maintenance is not required to assure proper overcurrent operation for current-limiting fuses, the protection from arc flash hazards remains constant through the life of the installation.

In order to determine the incident energy for current-limiting fuses, IEEE Std 1584™ is typically used. There are both general equations, where the calculated arcing current and time-current curves are used to determine incident energy, and “simplified” equations, where only the bolted fault current, fuse class, and ampacity are required to determine the incident energy. However, the simplified equations are based on actual testing for one manufacturer's fuse class only. Because of this, it is recommended that manufacturer

data or incident energy tables that are based on actual testing are used for the specific manufacturer's class and type of fuse when available and appropriate for the system characteristics in lieu of either the general or simplified equations.

8. Special applications for low-voltage fuses

8.1 Bus-bracing requirements

Reduced bus-bracing, now referred to as short-circuit current ratings, may be attained when current-limiting fuses are used. Figure 17 shows an 800 A motor-control center being protected by 800 A Class L fuses. The maximum available fault current to the motor-control center is 40 000 A rms symmetrical. If a non-current-limiting device were used ahead of the motor-control center, the short-circuit current rating required would be a minimum of 40 000 A rms symmetrical, with a peak value of 92 000 A ($2.3 \times 40\,000$ A) for a time period adequate for the actual clearing time of the non-current-limiting device. Note that equipment bus is typically rated for 3 or 6 cycles, but should be verified with the manufacturer. If the overcurrent device clearing time exceeds this value (some non-current-limiting overcurrent devices have clearing times up to 30 cycles), then the equipment has not been applied in accordance with its ratings. However, in this example with current-limiting fuses, the maximum peak current has been reduced from 92 000 A to 38 000 A with a corresponding reduction in effective rms available current from 40 000 A to 16 500 A and clearing time of 0.5 cycle or less. As a result, bus bracing of 16 500 A or greater is possible rather than requiring the full 40 000 A bracing. Some equipment bus is now listed with short-circuit current ratings based on specific types and sizes of current-limiting fuses. The equipment manufacturer should be consulted for these specific combination ratings.

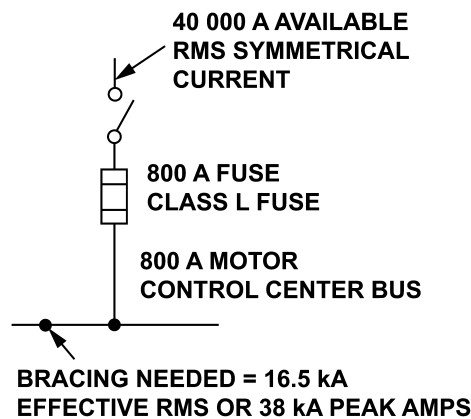


Figure 17—Example for determining bus-bracing requirements of 800 A motor-control center

8.2 Circuit breaker protection

8.2.1 New construction

For all new construction, only tested combinations of current-limiting fuses and molded case, insulated case, and power circuit breakers are allowed to be applied if the available fault current exceeds the marked interrupting rating of the circuit breaker. Nationally recognized testing laboratories have developed a set of tests that establish that a particular fuse and circuit breaker combination will successfully clear a fault in

specific equipment. These successful combinations are given a series rating and are typically published in recognized component directories. These recognized combinations should be specified for use in meter centers, load centers, panelboards, and switchboards that have been tested, listed, and marked for their use. The equipment manufacturers should be consulted for proper applications. See NEC 240.86(B) (NFPA 70-2017) and CEC 14-014 (CSA C22.1-2018).

8.2.2 Existing construction

For existing installations only, circuit breakers protected by current-limiting fuses may be applied in circuits where the available short-circuit current exceeds the interrupting rating of the circuit breakers, provided the circuit breakers are “passive” during the interruption period of the line side current-limiting fuse. The NEC requirements permitting this require the selection and evaluation be performed by a licensed engineer engaged in the design and maintenance of electrical installations. The interrupting rating for older style non-dynamic impedance or “passive” circuit breakers can be compared to fuse let-through current values to determine the proper protection. Such an engineered system will typically require older design power circuit breakers with minimum opening times of three cycles or more. Using present methods, engineering protection for modern molded case and insulated case circuit breakers exhibiting dynamic impedance through the use of repulsion (or blow-apart) contacts is not possible. The equipment manufacturers should be consulted for proper applications. See NEC 240.86(A) (NFPA 70-2017).

An example of applying fuses to protect molded case circuit breakers is given in Figure 18 where an older 225 A lighting panel has “passive” circuit breakers with an interrupting rating of 14 000 A rms symmetrical. The available fault current at the line side of the lighting panel is 40 000 A rms symmetrical. A 400 A RK-1 fuse would reduce the current at the circuit breakers to an effective 10 000 A rms available. With this significant level of current limitation by the fuse ahead of the circuit breaker, the circuit breaker will interrupt an effectively lower short circuit that is within its interrupting rating.

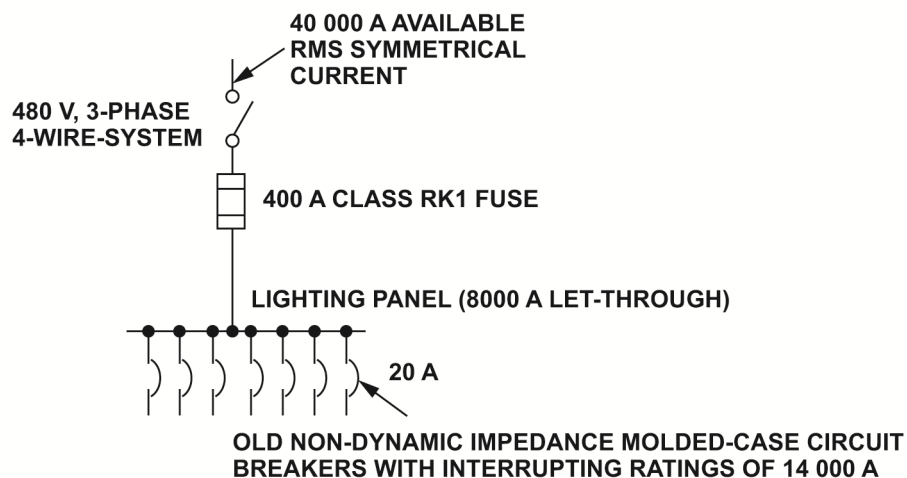
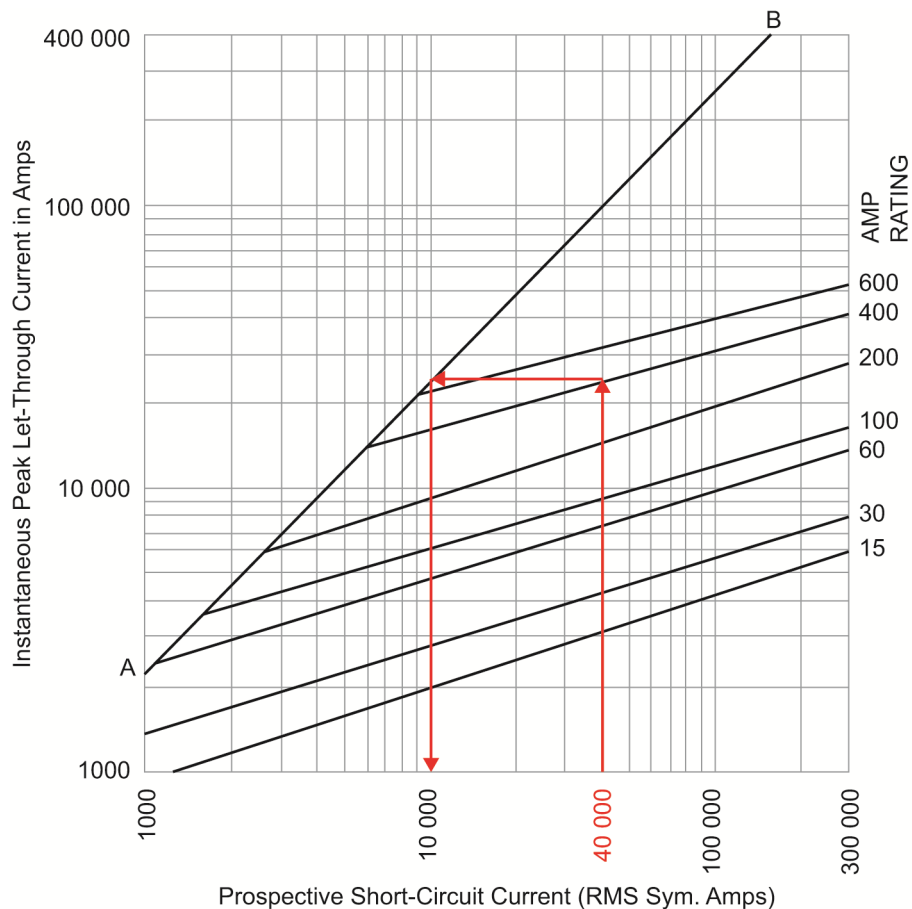


Figure 18—Application of fuses to protect molded case circuit breakers

8.2.3 Additional considerations

There are limitations or considerations when using series ratings. First, series ratings cannot be applied per NEC 240.86(C) (NFPA 70) if motors are connected between the line side overcurrent protective device and load-side circuit breaker and the total motor full-load currents exceed 1% of the interrupting rating of the load-side circuit breaker. Another consideration is that series ratings can result in a lack of

selective coordination. As such, series ratings should not be applied where selective coordination is required unless documentation from the circuit breaker manufacturer states that it is possible.

8.3 Wire and cable protection

Fuses should be sized for conductor protection according to the NEC (NFPA 70). When non-current-limiting fuses are used, reference should be made to the insulated cable thermal damage charts for short-circuit withstands of copper and aluminum cable in ICEA P-32-382-1999.

When current-limiting nontime-delay fuses are used for motor branch circuit protection, the conductors are protected from high-magnitude short-circuit currents even though the fuse may be 300% to 400% of the motor full-load rating as allowed by the NEC (NFPA 70). For protection of 16 AWG or 18 AWG conductors, properly sized Class CC, J, or T fuses may be required in accordance with NEC 240.4(D) (NFPA 70). See IEEE P3004.7/D6 [B5] for more information.

8.4 Automatic transfer switch (ATS) protection

UL tests automatic transfer switches under short-circuit conditions (see UL 1008). The short-circuit tests performed are used to establish the short-circuit current rating, based on a specific overcurrent device. For circuit breakers, the short-circuit current rating of the automatic transfer switch depends on whether the circuit breaker is equipped with a short-time delay function or instantaneous trip. With circuit breakers, to achieve higher short-circuit current ratings, typically larger ampacity automatic transfer switches are required. However, when protected by current-limiting fuses, high short-circuit current ratings are typically achieved. The short-circuit current ratings for automatic transfer switches vary by manufacturer; an example of short-circuit current ratings (sometimes called a *withstand rating*, *close-on rating*, or *withstand and closing rating [WCR]*) is shown in Table 12.

Table 12—Example short-circuit current ratings for one manufacturer's automatic transfer switch (Reprinted with permission from EATON Bussmann Div)

ATS UL 1008 Withstand and Close-On Ratings (WCR) (Sym RMS Amp)											
ATS Protected by Circuit Breaker								ATS Protected by Current-Limiting Fuse			
Transfer Switch Amp Rating	1		2		3			4			
	ATS Specific Circuit Breaker WCR Note 1	Max. Voltage	ATS Any Circuit Breaker WCR Note 2	Max. Voltage	ATS Short Time WCR (Circuit Breaker without instantaneous Trip)			ATS Fuse WCR	Fuse Max. Amp Rating	Fuse UL Class	Max. Voltage
					WCR Rating	Duration Cycles	Max. Voltage				
40	NA	-	10,000	600	NA	-	-	200,000	60	J	600
70, 100	22,000	480	10,000	600	NA	-	-	200,000	200	J	600
125, 150, 200	22,000	480	10,000	480	NA	-	-	200,000	300	J	600
260, 400, 600	50,000	480	42,000	480	30,000	24	480	200,000	600 800	J L	600
800, 1000, 1200	65,000	600	50,000	600	35,000	18	480	200,000	1600	L	600
1600, 2000	100,000	480	100,000	600	65,000	30	480	200,000	3000	L	600

1. WCR with specific circuit breaker: with this option the ATS manufacturer will provide a list of specific circuit breakers detailing the circuit breaker manufacturer, CB type or series, max. voltage, max. amp rating, and ATS WCR rating with that specific CB. Contact ATS manufacturer.
2. WCR with "Any" circuit breaker: the circuit breakers for this option must have an instantaneous trip and clear within 3 cycles (1.5 cycle clearing for switches 400A and less and tested for 10,000A WCR). The circuit breaker ampere rating would be based on NEC® requirements.

8.5 Motor starter short-circuit protection

UL tests motor starters under short-circuit conditions (see UL 508). The short-circuit test performed are used to establish the short-circuit current rating, often based on a specific overcurrent device and combination of components for motor starters. UL tests motor starters of 50 hp (37 kW) and under with a minimum of 5000 A of available short-circuit current. Starters over 50 hp (37 kW) in size are tested in similar fashion, except with greater available fault currents. Higher short-circuit current ratings than the minimum required based on horsepower are optional.

Figure 19 is a typical one-line diagram of a motor circuit, where the available short-circuit current has been calculated to be 40 000 A rms symmetrical. In this case, the starter has been investigated and found acceptable for fault levels through 100 000 A when protected by Class J fuses. IEC 60947-4-1 describes two types of motor controller protection in terms of the extent of damage to which the motor controller is subjected during a short circuit. Type 1 protection is similar to the requirements for listing in UL 508, but the controller may still need to be replaced because of the significant amount of damage allowed. Type 2 protection is much more restrictive and allows no permanent damage to the controller. Many motor controller manufacturers have had UL verify their controllers with Class CC, Class J, and Class RK-1 fuses for Type 2 protection in compliance with IEC 60947-4-1 and UL 508E. The motor controller manufacturers or fuse manufacturers should be consulted for lists of specific fuses to use with specific controllers (NEMA [B8]).

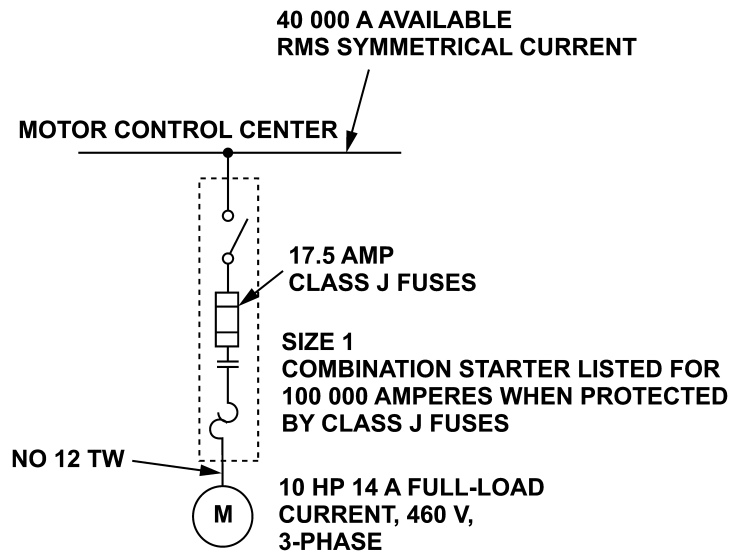


Figure 19—Application of fuses to provide short-circuit protection and backup protection for motor starters

8.6 Motor overcurrent protection

Single- and three-phase motors can be protected by specifying time-delay fuses for motor-running overload protection according to the NEC (NFPA 70). These ratings depend on service factor, temperature rise, and application (e.g., jogging). Where motor overload relays are used in motor starters, a larger size time-delay fuse may be used to coordinate with the motor overload relays and provide short-circuit protection.

Combination motor starters that employ overload relays sized for motor-running protection (maximum of 115% for 1.0 service factor and 125% for 1.15 service factor) can incorporate time-delay fuses sized at 115% (1.0 service factor) or 125% (1.15 service factor) or the next larger size to serve as backup protection. (Larger time-delay fuses, sized up to 175%, may be used for branch circuit protection only.) A combination motor starter with backup fuses provides excellent protection, motor control, and flexibility. Figure 20 illustrates the use of fuses for protection of a typical motor circuit.

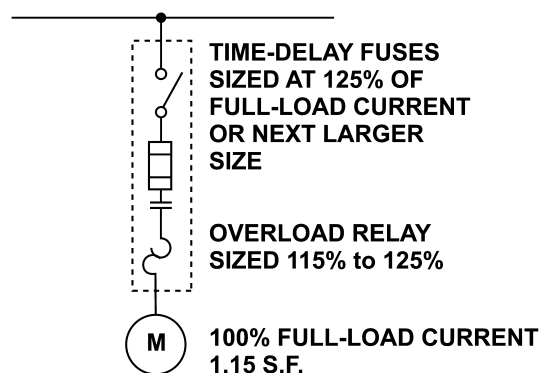


Figure 20—Application of time-delay fuses for typical motor circuit

When motors are operated near full-load, single-phasing protection may be provided by time-delay fuses sized at approximately 125% of the motor full-load current. Loss of one phase, either primary or secondary, results in an increase in the line current to the motor. This change is sensed by the motor fuses because the fuses are sized at 125%, and the single-phasing current opens the fuses. If the motors are operated at less than full load, the overload relays and time-delay fuses should be sized to the actual running amperes of the motor. For example, if a motor with a full-load rating of 10 A is being used in a situation where it is drawing only 8 A, the time-delay fuses should be sized at 10 A instead of 12 A. Another option is to utilize anti-single-phasing motor overload relays. See IEEE Std 3004.8™ [B6] for more information.

8.7 Transformer protection

Medium-voltage distribution transformers are often equipped on the primary side (above 600 V) with medium-voltage fuses sized for short-circuit protection. Transformer overload protection may be provided by fusing the low-voltage secondary with appropriate fuses sized at 100% to 125% of the transformer secondary full-load amperes. Figure 21 shows a proper size of low-voltage fuse for a 1000 kVA transformer to provide overload protection.

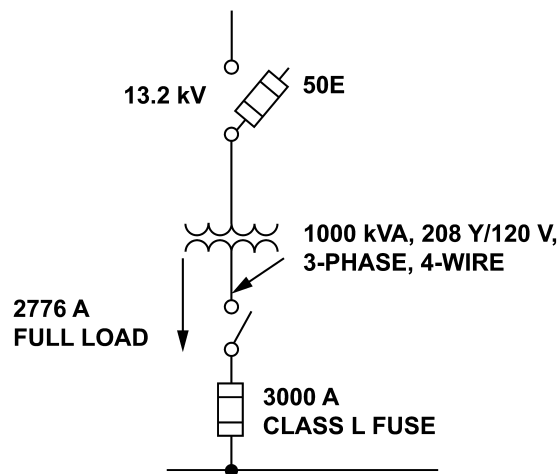


Figure 21 —Sizing of low-voltage fuses for transformer secondary protection

Transformers are frequently used in low-voltage electrical distribution systems to transform 480 V to 208Y/120 V. For these types of transformers, appropriate time-delay fuses should be provided, sized at 100% to 125% of the primary full-load current. Consideration should be given to the magnetizing inrush current because transformers have inrush currents equivalent to about 12, or even as high as 18, times full-load rating with a duration of 0.1 s (also about 20 to 25 times rating for 0.01 s).

Inrush currents can be easily checked against the minimum melting curve so that needless opening may be avoided. If necessary, a larger size time-delay fuse may need to be selected. The NEC permits sizing of the primary fuse up to 250% when secondary protection is provided at 125% or less. Figure 22 shows a 225 kVA lighting transformer with time-delay fuses. See IEEE Std 242™-2001, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems [B4] for transformer protection.

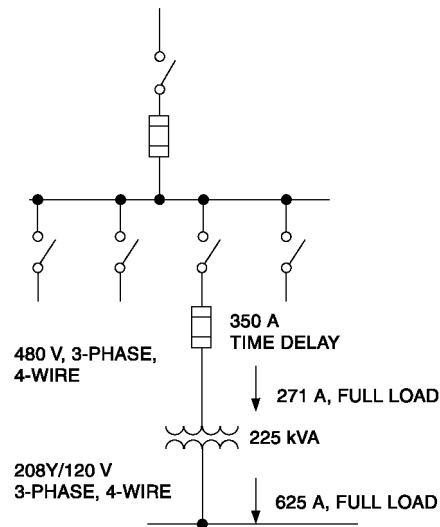


Figure 22 —Application of time-delay fuses for transformer protection

8.8 DC application

Most dc systems require some form of overcurrent and/or short-circuit protection (Brozek [B2]). These systems include dc motor drives and controllers, semiconductor components, telecommunication switching stations (both power and signal), electrical relay and control circuits for medium-voltage circuit breakers, and transit substations. Battery-powered applications from automobiles and factory warehouse vehicles to more sophisticated loads such as uninterruptible power supply (UPS, or battery backup) systems also require dc overcurrent protection. As with any fuse selection, the three elements of system voltage, normal load current, and available short-circuit current should be considered. For proper application, the fuse's ratings should equal or exceed the system parameters. The user should always obtain the proper dc data from the manufacturer.

Furthermore, the manufacturer's dc test data may not necessarily apply to the dc system at hand. Factors including circuit time constant, voltage, and available short-circuit current may preclude the use of certain dc-rated fuses.

A common misconception is that all published ac fuse data may be used for those same fuses on dc systems. Time-current curves that predict a fuse opening time under overload conditions can be used for ac and sometimes dc current. These curves are typically based on rms current, which is thermally equivalent to dc current. However, dc applications have an added twist in that the time constant of the system should also be considered. The dc time constant affects the melting and clearing time of the fuse under overload and short-circuit conditions. The net result is typically a lower voltage rating for the fuse. UL 248-1 outlines the required time constant required for overload and short-circuit testing.

8.8.1 UL 248-1

UL 248-1 defines the requirements and test procedures for dc-rated fuses for industrial use in accordance with the NEC (NFPA 70). Fuses that are tested to UL 248-1 should first meet the requirements of their respective ac standard.

8.8.2 Overload test

Fuse selection for the overload test is based on internal construction and body size (see UL 248-1). The largest ampere rating for each internal design and/or body size is sampled. For fuses with current ratings of 600 A or less, the fuses are tested to open 200% of the current rating at rated dc voltage. If the fuses are marked “time delay” or “D,” the fuses are additionally tested to open 900% of the current rating at rated dc voltage. For fuses with current ratings greater than 600 A, the fuses are tested to open 200% to 300% of the current rating at rated dc voltage. There is no additional test required for fuses marked “time delay.” For the 200%, 200% to 300%, and 900% test, the test voltage is maintained for 1 min after circuit interruption to ensure that the fuse has permanently cleared the circuit. To pass the test, the fuse casing cannot char or rupture, and external solder connections cannot melt. The time required for the fuse to clear is not specified. The time constant required for these tests cannot be less than the value given by:

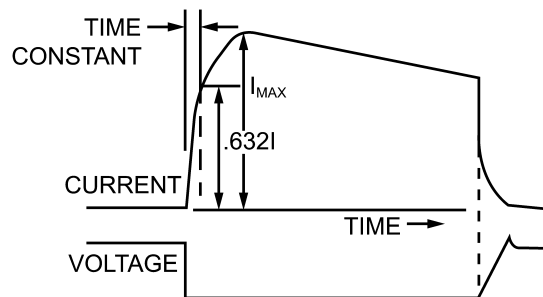
$$T = \frac{I^{0.3}}{2} \quad (1)$$

where

T is the time constant (ms)

I is the test current (A)

The time constant is the time required for the current to reach 63.2% of the test current and is shown in Figure 23.



**Figure 23—Time constant for dc circuits per UL 248-1
(Reprinted with permission from UL)**

8.8.3 Short-circuit interrupting test

To establish the short-circuit interrupting rating, fuses are tested at one of the following dc voltage levels: 60 V, 125 V, 160 V, 250 V, 300 V, 400 V, 500 V, or 600 V (see UL 248-1). A Class H fuse has a maximum dc interrupting rating of 10 000 A. A Class G fuse has a maximum dc interrupting rating of 10 000 A, 20 000 A, 50 000 A, or 100 000 A. All other classes rated 600 A or less have maximum dc interrupting ratings of 10 000 A, 20 000 A, 50 000 A, 100 000 A, 150 000 A, or 200 000 A. The time constant for these heavy short-circuit tests cannot be less than 10 ms. As in the overload test, the largest ampere rating for each internal design and/or body size is sampled. To pass, the fuse should remain intact and permanently clear the circuit. The overall length of the cylindrical portion of the fuse cannot be deformed more than 3.2 mm, and molten solder cannot be emitted. After interruption, the recovery voltage is continuously applied for 30 s to ensure that the fuse has become quiescent. Evidence of smoking, unusual heating, or internal arcing during this period is unacceptable. When the interrupting ability test is conducted

above 10 000 A, the peak let-through current and clearing I^2t cannot exceed the established ac values for the respective fuse class.

8.8.4 Maximum energy test

The final short-circuit test for fuse types with interrupting ratings greater than 10 000 A is the maximum energy test (see UL 248-1). These fuses should interrupt short-circuit current of at least 10 000 A and limit the peak let-through current to 60% to 80% of the peak available. The largest ampere size of each fuse body size is sampled.

Fuses listed to UL 248-1 typically are rated at a dc voltage level lower than the ac rating. The lower voltage rating is a direct result of the time constant requirement within the standard.

8.8.5 Mine duty fuses

UL 198M is an additional procedure to list Class K and Class R fuses intended for use in protecting trailing cables in dc circuits in mines. The standard follows Mine Safety and Health Administration (MSHA) requirements. Fuses tested to UL 198M should first comply with their respective ac standard. The dc voltage ratings for UL 198M are 300 V or 600 V. The largest ampere rating for each internal design and/or body size is sampled after temperature and humidity conditioning. The overload and short-circuit requirements are given in Table 13.

Table 13—Tests of fuses (Source: UL 198M)

200% clearing at rated voltage ^a
300% clearing at rated voltage ^b
900% overload at rated voltage
Interrupting ability at 10 000 A
Interrupting ability at 20 000 A

^a For fuses with a rating 200 A or less

^b For fuses with a rating greater than 200 A

The minimum time constants for this test are shown in Table 14. The time constants required for UL 198M are greater than the time constants in UL 248-1. Fuses are tested both in open fuse clips and in trolley-tap fuseholders. After the fuse interrupts the circuit, the test voltage is applied for 30 s. Performance is acceptable if the fuse clears without excessive smoking or excessive venting of gases.

Table 14—Circuit time constants

Test current (A)	Time constant (ms)
0 to 99	2
100 to 999	6
1000 to 9999	8
+10 000	16

Superficial damage to the fuse is allowable, that is, a maximum of 1.588 mm hole in any metal part of fuse or a maximum of one 3.175 mm opening in any nonmetal part of the fuse. Restrike is allowable within 30 ms of initial current interruption. If a restrike occurs, the test voltage is again applied for 30 s, and no further restriking is allowable. Fuses tested in the trolley tap fuseholder cannot damage the fuseholder. UL 198M does not specify peak allowable let-through current or maximum I^2t values. It is exceedingly difficult for fuses to just survive this test because of the voltage constraints and relatively long time

constants. For a better understanding of how these parameters affect the fuse, an explanation of circuit time constant is given in 8.8.6.

8.8.6 DC time constant

The circuit time constant is the time required for the current to reach 63.2% of the peak current and may be stated as follows:

$$I = (1 - e^{-1})I_p \quad (2)$$

where

I is current (A) at one time constant

I_p is maximum peak current (A)

The time constant can be calculated by taking the ratio of inductance to resistance L/R in the circuit. In simple terms, magnetic energy (in joules) is stored in the inductance (in henrys) and opposes any change in current (in amperes). The relationship between energy and inductance is shown as follows:

$$U = \left(\frac{1}{2}\right)Li^2 \quad (3)$$

where

U is magnetic energy (J)

L is inductance (H)

i is current (A)

For a circuit with a given resistance, a large inductance causes a slow rate of current rise, and negligible inductance has a fast current rise. The maximum value to which the current rises is limited by the circuit resistance. As a rule of thumb, fuses applied at rated voltage on dc circuits, having time constants less than 2 ms, have short-circuit melting and clearing characteristics similar to fuses applied on ac circuits with short-circuit power factors of 15% or greater. This assumption can be made because the current rise time di/dt is comparable.

8.8.7 DC voltage ratings

To meet the requirements in UL 248-1, the dc voltage ratings of industrial power fuses are typically derated to about one half of the ac voltage rating. The voltage derating decreases the arcing time needed to equalize to the system voltage, decreases the arcing I^2t , and maintains clearing I^2t to below the allowable levels. Semiconductor fuses that are designed primarily for dc systems typically have voltage derating charts for a given time constant. One manufacturer's voltage derating table for semiconductor fuses is shown in Table 15.

Table 15—Voltage derating versus time constant^a

Time constant (L/R) ms	Percentage of rated voltage (rms)	
	700 V fuses	1000 V fuses
5	80% to 90%	85% to 95%
10	70% to 80%	80% to 90%
20	60% to 70%	70% to 85%
30	55% to 70%	65% to 80%
40	50% to 65%	60% to 75%
50	50% to 65%	55% to 70%
60	45% to 60%	50% to 65%

^aBased on fuse opening time of 25 ms to 300 ms.

For most battery-protection applications, fuse operation is straightforward and reliable. Batteries contain little inductance and, as stated by one large UPS manufacturer, a shorted battery is similar to a fault through a resistor. A shorted battery drains rapidly and gives rise to high di/dt . Fuses listed to UL 248-1-2011 (and certainly UL 198M) are generally applicable for UPS battery protection. Proper placement of the fuse in a battery circuit is beyond the scope of this recommended practice (Nailen [B7]). For applications where inductive loads are present (e.g., in motors, solenoids, any other coil loads), the circuit time constant should be determined to ensure proper application of the fuse. By specifying fuses with a rated dc voltage beyond the system voltage, the user incorporates more leeway into the allowable time constants. If the dc voltage capability in a particular fuse application is uncertain, the fuse manufacturer should be consulted.

8.9 Photovoltaic applications

Fuses that are specifically designed for photovoltaic applications are tested and listed to UL 248-19 and CSA C22.2 No 248.19. Photovoltaic (PV) fuses are specifically designed to protect solar power systems in extreme ambient temperature, high cycling, and low-level fault current conditions. Photovoltaic fuses can be rated as high as 1500 V, with a minimum interrupting rating of 10 000 A and must be marked “PV,” “gPV,” or “Photovoltaic Fuse.”

Photovoltaic fuses are tested to the requirements similar to UL 248-1 with regards to current carrying capacity at 100%, and overload operation at 135% and 200% of rated current. For verification of operation at rated dc voltage, the fuses are tested at 200% and 10 000 A, with the exception that the time constant is 1 ms or less. However, fuses that comply with IEC 60269-6 must be tested for a time constant of 3 ms or less.

Additional testing beyond the basic requirements of UL 248-1 with regards to service environment conditions are required such as verification of freedom from unacceptable levels of thermally induced drift, verification of functionality at temperature extremes, and current cycling is required.

For the verification of freedom from unacceptable thermally induced drift, samples are submitted to 50 cycles of heating and cooling, from -40°C to 90°C , for periods of 15 min each. At the conclusion of the cycling, the fuses are subjected to the overload operation and verification of operation at dc voltage test mentioned previously.

For the verification of functionality at temperature extremes, the fuses are conditioned and maintained at -50°C , then tested for verification of current carrying capacity of 100% and verification of overload at 35%.

For the current cycling tests, there are two sets of tests required. The first set requires the fuses to be cycled in a temperature chamber for 50 cycles of heating and cooling, from -40°C to 90°C , for periods of 15 min each. At the conclusion of the temperature cycling, the fuses are subjected to 3000 repetitions of current cycling as shown in Figure 24. The second set of tests requires the fuses to be conditioned in a

humidity chamber at 25° C, 90% to 100% humidity for a minimum of 5 days. Within one hour of the removal from the humidity chamber, the fuses are subjected to 3000 repetitions of the current cycling shown in Figure 24. After both sets of tests, the fuses are returned to room temperature and resistance must not differ more than 10% of the initial resistance before the testing, and the fuses can not have cracking or crazing of the fuse body.

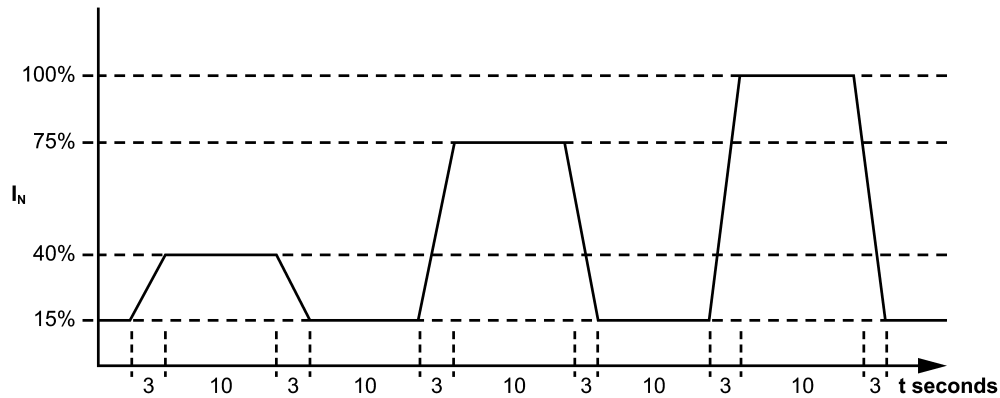


Figure 24—Current cycling test profile for photovoltaic fuses
(Reprinted with permission from UL)

8.10 100% rated equipment

The fuse standards have testing and evaluation criteria for fuses. The fuses are tested to carry current continuously per the test procedure and evaluation criteria of the specific fuse standard (100% for some UL fuse classes and 110% for others). At the time of this publication, the UL 248 fuse tests and evaluation procedures have the fuses in open air at “normal” room temperature of 25 °C (77 °F), and connected with typical conductor ampacity. However, practical applications have the fuse in an enclosure with other heat-generating components. For most practical applications, a branch circuit fuse is sized to carry 125% of the continuous load, and this accounts for the difference between fuse testing in open air and actual real world conditions in an enclosure.

The UL 98 switch standard does not have provisions for a fusible switch to be rated 100% for continuous loads. They are rated for 80% continuous load. For a 30 A fuse in a 30 A switch, the continuous load can be as high as 24 A. The one exception to this rule is that motor switches only need to be rated at 115% of motor full-load current.

UL 977 Standard Fused Power Circuit devices have provisions for 100% rated fusible switches in an assembly. Several manufacturers market UL 977 bolted pressure switches that have been investigated for 100% rating with Class L and/or Class T fuses. However, if these UL 977 bolted pressure switches are installed in a switchboard, then the switchboard manufacturer may have to provide certain provisions to their gear that were part of fused power circuit device conditions in meeting the UL 977 100% ratings. For instance, a UL 977 bolted pressure switch may require vents on the enclosure in order to pass the 100% rating criteria, or there may be a condition for a minimum volume of the enclosure for a 100% rated switch.

In summary, for a fuse and switch assembly to be 100% rated, at least two things typically have to happen:

- The fusible switch component must be listed at the 100% rating.
- The assembly in which the fusible switch component is installed must be listed with provisions for 100% rating with the specific fusible switch component, and the assembly must meet minimum requirements (such as vents) if the component’s listing has stipulations.

Annex A

(informative)

Bibliography

Bibliographical references are resources that provide additional or helpful material but do not need to be understood or used to implement this standard. Reference to these resources is made for informational use only.

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¹⁴ Numbers preceded by P are IEEE authorized standards projects that were not approved by the IEEE SA Standards Board at the time this publication went to press. For information about obtaining drafts, contact IEEE.

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